

BOOK OF ABSTRACTS



XII INTERNATIONAL VACCINIUM SYMPOSIUM

AUGUST 30 – SEPTEMBER 1, 2021

ISHS
International Society for Horticultural Science



**DALHOUSIE
UNIVERSITY**

BOOK OF ABSTRACTS

XII INTERNATIONAL
VACCINIUM
SYMPOSIUM

August 30 – September 1

HOSTED BY



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International Vaccinium Symposium

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Organizing Committee

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Keynote Speakers

Speaker: David Brazelton

Presentation Title: Blueberries: Where have we been and where are we going?



David Brazelton is chairman of the Board of Directors for Fall Creek Farm & Nursery and is a founder of the family-owned company. After buying the initial farm in 1978 with his wife Barbara, Dave dedicated his career to the development of a dynamic and sustainable blueberry industry worldwide with a commitment to top-quality plant supply, innovative varieties, and horticultural support. Dave has held many industry positions, such as Chairman of the Oregon Blueberry Commission and is the current Chairman of the United States Highbush Blueberry Council Health Research committee. Fall Creek is a world leader in blueberry variety development and nursery stock production with operations in the US, Mexico, Chile, Peru, Holland, Spain, and South Africa.

Speaker: Laura Jaakola

Presentation Title: Phenolic compounds in *Vaccinium* spp.: diversity, biosynthesis, and molecular regulation



Professor Laura Jaakola is holding a position as Research leader of the Climate Laboratory Holt, UiT the Arctic University of Norway in Tromsø, which is a joint unit of UiT and the Norwegian Institute of Bioeconomy (NIBIO). She has a scientific background in plant physiology and molecular biology. Her research activities have focused largely on the North European wild berries and the biosynthesis of secondary metabolites, especially anthocyanins and other phenolic compounds. The main interest has been in the developmental control of the biosynthesis of the key metabolites in berries and the environmental and genetic factors that regulate the processes. She has numerous international publications and a wide international collaboration network.

Dear colleagues,

It was with honor, appreciation, and optimism that we undertook preparations to host the Twelfth International Vaccinium Symposium back in 2016. With Canada never hosting the Symposium, it was our hope to develop a solid scientific program that would engage researchers from across the world while also providing an opportunity to see the unique nature of the wild blueberry production system as well as the cranberry and cultivated highbush blueberry sectors.

Unfortunately, just after the call for abstracts closed in February 2020, the realities of the COVID-19 pandemic became apparent with tremendous personal and professional losses, turmoil, sadness, pain, and poverty. We soon realized that it would not be possible with the Symposium in August 2020, so rescheduled to August 2021. Uncertainties existed with respect to the venues and facilities that were to have been used with the decision being made to defer their use until it is safe for international travel to occur and there be no negative impact on other meetings including the ISHS HortCongress. This was complimented with the loss of support to the Symposium as organizations focused on surviving and contending with the realities of COVID-19. The realities of COVID-19 also came apparent to Nova Scotia this April with a surge of cases and a lockdown with restrictions only recently being eased.

Throughout these uncertain times, the desire to hold the Symposium has not wavered. The decision was made in February to proceed virtually and to give authors the opportunity to present their oral and poster contributions; interact with other researchers, technology transfer specialists and industry representatives in a virtual format; and also publish their results in the conference proceedings. Registration fees were also significantly reduced to try and reduce the financial burden on researchers while simultaneously allowing the Symposium to try new virtual conference technologies. The Symposium will include regular plenary and technical sessions, the awards ceremony as well as spaces in which to connect with exhibitors and educators from across the globe. In addition, all attendees will have access to on-demand recordings after the completion of the live conference. You can join us live or watch recordings from your computer, tablet, or phone, at your leisure.

The Organizing Committee would like to extend our sincerest gratitude to those continuing to participate in this Symposium. We hope that despite the present realities of COVID-19, the Symposium opens up a world of learning opportunities, possibilities to innovate, and connect with the Vaccinium Community around the world. We look forward to seeing you at IVS 2024!

David Percival

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**SPEAKER ABSTRACTS
LISTED IN ORDER OF PRESENTATION**

Technical Session 1: Plant Physiology and Plant Nutrition

Moderator: Peter Jeranyama

Optimal nitrogen fertilizer application rates for second-generation cranberry hybrids

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Nitrogen (N) is the most important element in cranberry (*Vaccinium macrocarpon* Ait.) production due to its impact on both vegetative growth and fruiting. However, N is also naturally deficient in acidic peatland soils, which require N fertilizer additions for commercial production of cranberry. Nitrogen fertilizer rates have been previously determined for native cultivars and for the first-generation hybrids, but field data to support N fertilizer recommendations for second-generation hybrids are lacking. To fill this gap, we conducted a replicated field experiment to develop N rate response curves for native, first- and second-generation hybrids, and to evaluate the effect of field fruit rot as influenced by fertilizer N rate on native and hybrid cultivars. We tested the most common types of native ('Howes'), first-generation hybrid ('Stevens'), and second-generation hybrid ('Crimson Queen', 'Demoranville' and 'Mullica Queen') cultivars planted in Massachusetts cranberry bogs. Our results showed that fruit yield was highest at the N fertilizer application rate of 112 Kg N ha⁻¹ for second-generation hybrids, 84 Kg N ha⁻¹ for first-generation hybrids, and up to 56 Kg N ha⁻¹ for native cultivars. Vegetative biomass increased linearly with N rate regardless of cultivar. Nitrogen fertilizer rates greater than 112 kg N ha⁻¹ resulted in overly vigorous vegetative growth that diminished fruit production. Fruit rot generally increased with N fertilizer application rate, with up to 40% fruit rot observed in 'Crimson Queen' at the highest N fertilizer rate of 224 Kg N ha⁻¹. The results seem to suggest that for optimal fruit yield, N fertilizer recommendations for first-generation hybrids are inadequate for second-generation hybrids.

Keywords: Cranberry hybrids, fertilizer, nitrogen, fruit rot

Sectorial pruning of highbush blueberries: long-term effects on yield and fruit quality

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Labor is becoming scarce in many blueberry-growing regions. After harvest, pruning is the practice requiring most labor. A new approach called sectorial pruning (SP), in which each winter all canes in one quarter of the plant are removed at the base, was trialed for three years in twelve-year-old 'Brigitta' plants growing in a commercial field in Linares, Chile (Latitude 35° S). SP was compared with quick pruning (QP) in which the oldest cane of each quarter was removed at the base from the plant. SP and QP removed each year 31 and 18 % of the total basal area of the plant, respectively. SP had higher yields only in year 1 (8.0 vs. 5.5 kg/plant). Pruning treatments had no effect of fruit number, but fruit weight was greater for SP in the first two years (32-39%). Regarding fruit quality, fruit diameter was increased by SP only in year 1 (14.2 vs. 13.3 mm); while QP had higher fruit firmness only in year 2 (153.6 vs. 122.1 g mm⁻¹). Considering the overall effects of the three seasons, pruning had no significant cumulative effects on yield and its components (fruit weight and number) or quality (fruit diameter and firmness). SP had on average 32% higher yields and its fruits were 19% heavier than QP. The most marked effects of SP on yield and fruit weight were detected in the first two seasons (32-45% greater than QP). The cumulative effects on fruit number, firmness and fruit diameter were milder and unstable. The reduction in yield with SP after the second season would be due to a greater proportion of older and highly productive canes being removed and replaced by younger unproductive canes. In this context, delaying the removal of the second and third quarters in SP might prove adequate to sustain high yields, while reducing the need for labor.

Keywords: Cane age, cane yield, yield components

Water requirement estimation of rabbiteye blueberry seedlings based on water surface evaporation method

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Water requirement estimation is one of the important aspects in crop water requirement research. In order to clarify the feasibility of water requirement estimation by water surface evaporation, actual water requirement of rabbiteye blueberry (*Vaccinium virgatum* Ait.) cultivar 'Brightwell' seedlings were measured by weighing lysimeter in this paper. Simultaneously, water surface evaporation above the canopy was estimated using the standard 20 cm evaporation pan. The relationship between actual water requirement and water surface evaporation was studied, and the water requirement model based on water surface evaporation was established:

$ET = D^2 \times E_{p-20} \times k/1000$, in which ET is the plant water use within a certain period, D is the diameter of the plant at drip line (cm), E_{p-20} is the measured evaporation from the standard 20 cm evaporation pan (cm), and k is the pan coefficient. The regression analysis results showed that estimation model for water requirement of "Brightwell" was $ET = D^2 \times E_{p-20} \times 0.246/1000$. According to the water requirement estimation model, the fitting value of evapotranspiration was obtained, and regression analysis was conducted for the relevance between estimated and measured evapotranspiration. There were significant positive correlations between the measured and estimated evapotranspiration, indicating that actual water requirement estimation by water surface evaporation above the canopy is feasible and effective. Our results provide reference and guidance for water management of rabbiteye blueberry under the similar climatic and geographical conditions.

Keywords: Water requirement; pan evaporation; water management; rabbiteye blueberry

Light quality from supplemental light-emitting diodes modulates secondary metabolites biosynthesis in ripening bilberry (*Vaccinium myrtillus* L.)

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Wild berries are abundant with health-beneficial bioactive compounds such as flavonoids, carotenoids, vitamins and other polyphenolic compounds, which in some species accumulate in both skin and flesh of the fruit throughout the ripening process. Interestingly, berries from northern latitudes are found to contain more bioactive compounds compared to southern clones. The genetic adaptation is most likely favored by environmental conditions such as extended day length, cool temperature and mainly the light spectral qualities. The molecular mechanisms underlying the regulation of secondary metabolites biosynthesis in response to light quality are less explored in *Vaccinium* berries. The present study is focused on gaining knowledge on the regulatory process under supplemental red and blue light in a non-climacteric berry species, wild bilberry (*Vaccinium myrtillus* L.). Controlled experiments have been carried out in phytotrons with local Norwegian ecotypes of bilberry, which were subjected to continuous exposure to specific wavelengths provided by light-emitting diodes from early to late ripening stages. Berry samples from mid- ripening stage were utilized for the gene expression analysis based on RNA-seq transcriptome profiling. Our recent analyses from the transcriptome dataset has shown that both light wavelengths tend to influence the abscisic acid metabolism, anthocyanin and carotenoid biosynthetic genes thus also resulting in higher concentration of delphinidin accumulation in ripe bilberries. The enhanced biosynthesis of such photoprotective compounds can be well correlated with altered expression changes observed in various protein subunit complexes of photosystem I & II in the photosynthetic apparatus. This is crucial to look upon in order to study how the plants acclimatize to modified monochromatic light environment in terms of photosynthesis when compared with the plants perceiving normal solar spectrum. The results will bring a better understanding of the light-mediated biosynthesis of phytochemicals in *Vaccinium* berries.

Keywords: Anthocyanins, *Vaccinium* berries, bilberry, LED light, photosynthesis

Technical Session 2: Breeding, Genetics, and Phenomics

Moderator: Lara Giongo

Comparative study on texture: a key trait for blueberry fruit quality breeding

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The consumption of blueberries has increased rapidly in the last decade, which has expanded blueberry production to new cultivation environments, requiring the shipment of fruit worldwide. Thus, the industry is facing new challenges with consumers demanding better quality fruit year-round. For consumers, better quality blueberries must have an attractive appearance, a good texture, and a pleasant flavour. A prolonged shelf life, from fruit harvest to retail, is an additional requirement for a blueberry cultivar. Thus, fruit texture is one of the most critical parameters of fruit quality in blueberry starting from breeding and must be fine-tuned to provide the industry with a standard phenotyping methodology.

To standardize the method for testing blueberry firmness, different texture analyser equipment and parameters were used on different cultivars. The following texture analyses were conducted: destructive penetration tests with flat cylindrical probes, needle probe and a non-destructive compression test were used to determine whether fruit texture is cultivar-dependent, and or related to fruit anatomical patterns. Additionally, the relationship between mechanical texture parameters, morphological traits and sensory quality characteristics was elucidated for a set of blueberry genotypes. The accuracy and discriminative power of texture analysis over cultivars and selections in different locations and post-harvest with different methods was examined and will be presented.

Keywords: Vaccinium, texture analysis, firmness, post-harvest storability

Using the genome database for *Vaccinium* for genetics, genomics, and breeding research

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The Genome Database for *Vaccinium* (GDV, www.vaccinium.org) is an easy-to-use, online, community database that provides access to publicly available data, and visualization and analysis tools, to enable basic, translational, and applied research in *Vaccinium* genetics, genomics, and breeding. The database contains genetic maps, genetic markers, germplasm, USDA-GRIN phenotype data, quantitative trait loci, gene, transcript, and annotated genome data from published manuscripts. These data are searchable through a customizable search interface, MegaSearch, or through specific data type searches. GDV has tools to view and compare genetic maps (MapView), genome annotations (JBrowse), metabolic pathways (PathwayTools), and gene expression as well as a BLAST tool for searching genome and transcriptome sequences. The Breeding Information Management System(BIMS) provides access to search, filter and analyze *Vaccinium* GRIN data and manage private breeding program data. As the community database for *Vaccinium*, GDV is home to the *Vaccinium* Coordinated Agriculture Project (VacCAP). The tools and resources available on GDV are based on user input and the needs of the research community and feedback is always welcome.

Keywords: Community database, genetics, genomics, breeding

Molecular variation, genetic structure and antioxidants in *Vaccinium* germplasm

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Blueberry, cranberry and lingonberry are three economically and medicinally high-value crop that belongs to the genus *Vaccinium* L. Global production of these crops increased significantly in recent years due to their potential health benefits. Evaluation of wild *Vaccinium* germplasm is of significant importance for their utilization in maintaining biodiversity and for proprietary-rights protection. Molecular diversity and antioxidant analyses in *Vaccinium* germplasm will facilitate not only for reliable genotypes classification but also for possible use directly as cultivars or in a breeding program. This review describes the progress of molecular diversity and antioxidant analyses in wild *Vaccinium* species and their utilization in genetic enhancement of *Vaccinium* berry crops for Northern Canada.

Keywords: Antioxidant properties, molecular diversity, *Vaccinium* species, wild germplasm

Characterization of population structure and genetic variation of chilling requirement in southern highbush blueberry

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Southern highbush blueberry (SHB) is a blueberry cultivar group developed by crosses between northern highbush [NHB (*V. corymbosum* L. $2n=4x=48$)] and indigenous blueberry species in Florida to expand the geographic limits of highbush blueberry production. Due to the multiple uses of interspecific hybridization in the breeding process, most SHB cultivars assumed to contain genomic segments introduced from the other *Vaccinium* species. Here we genotyped 108 accessions of SHB, 18 accessions of NHB and 10 accessions of rabbiteye blueberry (RE) by ddRAD-seq. SNPs were called with a threshold of 5% of alternative allele and without allelic dosage information, which yielded 43,176 genome-wide SNP loci as biallelic variants. The genome-wide SNPs analysis indicated that RE cultivars were genetically distinct from SHB and NHB cultivars, while NHB and SHB were not clearly separated. Among the SNPs regions, there was no allele that was detected in all the SHB individuals and absent in all the NHB individuals. This observation may suggest that it is unlikely that low-chill phenotype, an SHB common characteristics, is conferred by a single genomic segment introgressed from wild species as previously predicted. In addition, our genome scan analysis identified a few significant regions which were correlated with categorical values representing SHB and NHB. These regions may be possible candidates responsible for the SHB evolution. We also performed a genome-wide association study on 12 phenological and berry-related traits. Phenotypic data was collected at USDA-ARS, Mississippi. A significant peak for chilling requirement was detected in chromosome 4 for two consecutive years. The frequency of individuals with the low-chill allele in this region was approximately 20% in the SHB population and most of the NHB individuals were homozygous for the high-chill allele in this region. Currently, we are making further genome characterization of this region.

Keywords: Population genomics, ddRAD-seq, GWAS, dormancy

Technical Session 3: Berry Composition and Quality

Moderator: Katherine Ghantous

Concentration of quinclorac in cranberry plant tissue with repeated annual applications

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Quinclorac is an effective control for dodder (*Cuscuta* spp.) and other weed species in cranberry. Concerns that repeated annual use might increase fruit residues, and anecdotal reports of dodder control in the years after application raised questions about quinclorac persisting in cranberry tissues. A 2-year tissue-residue study and a 3-year yield-impact study were conducted on established 'Stevens' vines in Massachusetts. Small plots were treated with two applications (June and July) at 280 g a.i. ha⁻¹ quinclorac in each treatment year. Treatments for the tissue-residue study were applied two consecutive years in a row, while treatments for the yield-impact study were applications in Year (Y) 1 only, Y1 and Y2 only, or Y1, Y2, and Y3. Fruit were collected from each plot annually. Cranberry leaves and stems were collected annually and separated into current year growth ("new") and previous season's growth ("old"). Residues from tissue were extracted and analyzed by LC/MS/MS. After one year of two applications, quinclorac residues were detected in all tissue types. The lowest concentration of residue was detected in old stems. Plots treated again in Y2 had similar levels in leaves as those treated in Year 1, but the quinclorac concentration in stems approximately tripled from the previous year. Fruit collected in 2017 (Y3) were also analyzed for quinclorac residues, and showed no detects for plots treated in Y1 only and left untreated for two years before residue analysis, 25 ppb (mean, n=4) for plots treated in Y1 and Y2 and left untreated for one year before residue analysis, and 657 ppb (mean, n=4) for plots treated in all 3 years (U.S. tolerance=1500 ppb). Carryover of herbicide in stem tissue may account for weed control observed in the year following application.

Keywords: Dodder, *Cuscuta*, quinclorac, cranberry, pesticide residue

Method optimization and cell wall analysis for peel and pulp of blueberry cultivars

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Blueberry (*Vaccinium corymbosum*) quality drives consumer acceptance and market value. Retention of fruit firmness in fresh market blueberries is a critical quality component that dictates shelf-life. Inconsistent texture and reduced shelf-life of blueberries may be related to variations in cellulose, hemicellulose and pectin plant cell wall components. Six to eight neutral sugars have been previously identified in whole blueberry, but differentiation of the cell wall composition of blueberry peel and pulp has not been done to date. Methods were developed to separate peel and pulp of two blueberry cultivars with differing textures. Samples were flash-frozen in liquid nitrogen and ground using a Genogrinder. A randomized complete block design was used to test ball mill sizes and grinding times. Frozen samples of “Indigo Crisp” (high tissue firmness) and “Jewel” (low tissue firmness) were packed into 50 mL tubes with 20 mL of 95% ethanol. Grinding optimization consisted of grinding times for 4, 6, 8 or 10 min and ball mill sizes of 6 x 2.8 mm, 4 x 3.7 mm and 4 x 4.46 mm. Grinding samples for 6 min with 4 x 3.7 mm steel balls removed the peel in both blueberry cultivars. Further grinding of the peel with 6 x 2.8 mm steel balls for 6 min and pulp samples with 4 x 3.7 mm steel balls for 4 min was required to prepare the fractions for alcohol insoluble residue (AIR) extraction. Peel and pulp samples were then individually prepared into AIRs via hot ethanol extraction according to methods previously optimized in our laboratory for whole berry samples. In short, AIRs were prepared by use of cold or hot extraction. Grinding time, re-grinding of the AIR and sulfuric acid hydrolysis levels were also tested. For whole berry, hot ethanol extraction yielded AIRs with little color remaining. Re-grinding the AIR for 90 sec then applying 126 μ L of 72% sulfuric acid for 60 min with sonication was critical for complete hydrolysis of blueberry cell wall polysaccharides. Total cell wall composition analysis was performed on the resulting AIRs to determine neutral sugar composition and polysaccharide linkages. Complementary data on the total polysaccharide sequential fractions will be followed on multiple blueberry cultivars. Cell wall polysaccharide neutral sugar composition and linkage assembly will be determined in blueberry peel and pulp to study cell wall differences related to loss of berry firmness during storage.

Keywords: Blueberry, peel, pulp, cell wall, fruit quality

New tools for rapid fruit quality analysis in blueberry

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Blueberry fruit quality, defined here as size, firmness, color, and chemical composition, attracts consumer purchases while a positive sensory experience encourages repeat purchases. While these attributes are important in breeding programs, phenotyping traits using traditional methods is expensive and time consuming. This limits the ability of breeders to select for traits, and geneticists to perform genetic studies. Incorporation of NIR (near infrared spectrophotometry) was used to evaluate freeze dried fruits from 73 blueberry accessions for total and individual soluble sugars using algorithms developed from digital refractometer and high-performance liquid chromatography values. Total soluble sugar content ranges were 455-765 mg/g dwt. The sucrose content of fully ripe blueberries varied from below detection limit to 5% of total sugars, while fructose and glucose comprised 45-53 and 46-53% of total soluble sugars, respectively. NIR prediction model of sugars was 0.86 (fructose, glucose) to 0.90 (sucrose) R^2 .

As total pH and titratable acidity were poorly correlated with NIR, pocket pH and titratable acidity meters were used with blueberry puree; time to run samples was reduced by 40% compared to using an autotitrator. Using a similar approach, efforts are ongoing to establish a NIR calibration curve for total anthocyanin content. These methods offer a high-throughput and cost-effective approach for screening blueberry germplasm.

Keywords: Soluble sugars, glucose, fructose, titratable acidity, NIR

Technical Session 4: Pest Management

Moderator: Bill Cline

Diseases and insects of economic importance affecting blueberry fruit in North Carolina

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North Carolina (NC) is located on the mid-Atlantic coast of the United States within the native range of several *Vaccinium* species, including highbush blueberry. The main commercial production area is in the coastal plain of southeastern NC. Coastal plain production of northern highbush blueberry (*V. corymbosum*) is limited by soils and by lack of sufficient winter chilling, thus most commercial fields are devoted primarily to southern highbush (*V. corymbosum* X) and to a lesser extent rabbiteye (*V. virgatum*). Southern highbush cultivars grown in NC vary widely in chill requirement and bloom time, complicating the control measures for diseases and insects of fruit. Major fungal diseases of fruit include mummy berry (*Monilinia vaccinii-corymbosi*), exobasidium leaf and fruit spot (*Exobasidium maculosum*), anthracnose fruit rot (*Colletotrichum* spp.) alternaria fruit rot (*Alternaria tenuissima*) and botrytis flower blight and fruit rot (*Botrytis cinerea*). Major insect pests of fruit include blueberry maggotfly (*Rhagoletis mendax*), cherry fruitworm (*Grapholita packardii*), cranberry fruitworm (*Acrobasis vaccinii*), plum curculio (*Conotrachelus nenuphar*) and Spotted wing drosophila (*Drosophila suzukii*).

Key words: *V. corymbosum*, *V. virgatum*, mummy berry, exobasidium, anthracnose, Alternaria, Botrytis, maggotfly, cherry fruitworm, cranberry fruitworm, plum curculio, spotted wing drosophila

Assessing fungicide efficacy for improved management of the wild blueberry foliar disease complex in eastern Canada

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The wild blueberry foliar disease complex, comprised of blueberry leaf rust (*Thekospora minima*), Sphaerulina leaf spot (*Sphaerulina vaccinii*) and Valdensinia leaf spot (*Valdensinia heterodoxa*), significantly reduce yields when left unmanaged in the vegetative year of production. The once widely used chlorothalonil is no longer being used by many growers due to its deregistration in the European Union. Therefore, the objective of this study was to evaluate registered and future fungicide options for their impact on foliar diseases, leaf number and floral bud number. Field trials conducted in Collingwood Corner and Londonderry (Nova Scotia) consisted of ten treatments: untreated, mefentrifluconazole, mefentrifluconazole + fluxapyroxad, mefentrifluconazole + pydiflumetofen, pydiflumetofen, pydiflumetofen + difenoconazole, prothioconazole, fluopyram + prothioconazole, prothioconazole + benzovindiflupyr, and prothioconazole + pydiflumetofen. Mefentrifluconazole and pydiflumetofen are currently not registered for use on wild blueberries in Canada but, are expected to be available within the next few years. Disease pressure was significantly higher at the Londonderry location. At both locations prothioconazole + benzovindiflupyr treatments recorded the highest leaf number, with prothioconazole + benzovindiflupyr and prothioconazole + pydiflumetofen treatments resulting in lowest disease incidence. At the Londonderry location, the untreated treatment had the lowest floral bud number. This study demonstrates that the current industry standard tank mix of prothioconazole + benzovindiflupyr offers the greatest control of foliar diseases. Furthermore, this study shows that pydiflumetofen combined with prothioconazole can be considered part of the foliar disease management strategy once pydiflumetofen is registered for use on wild blueberries.

Keywords: *Vaccinium angustifolium*, *Vaccinium myrtilloides*, fungicides, foliar disease

Mummy berry forecast system improves control of disease in Maine lowbush blueberry

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Mummy berry (caused by *Monilinia vaccinii-corymbosi*, MVC) is potentially the most damaging disease in lowbush blueberries (*Vaccinium angustifolium*) in Maine. Prior to 2007, blueberry growers were making a first application of a protectant fungicide at early bud break with a subsequent application 7 to 10 days later. Many growers complained they were not achieving good control of mummy berry. In 2008, a mummy berry forecast system (MBFS), based on one developed in Canada by Paul Hildebrand and Rick Delbridge, was established in Maine. The MBFS involves tracking MVC and plant development and monitoring leaf wetness and temperature to indicate conditions for MVC infection. These data were used to provide growers with advice on suitable timing for fungicide applications for mummy berry control. Field trials comparing the calendar and MBFS methods were set up in multiple fields in 2009 and 2010. The MBFS method used fewer fungicide applications to produce the same level of control as the calendar method. Protocols were developed to establish and monitor development of MVC pseudosclerotia in the field. In 2012, weather stations with cellular telemetry were introduced to provide real-time data on weather conditions in the field. The current system uses grower involvement in reports of apothecial and plant development, and the fifteen weather stations to provide information on risk of mummy berry infection relayed to growers by multiple methods. Approximately 75% of Maine growers who use fungicides to control mummy berry use the MBFS to aid in timing of applications. Growers report they use fewer fungicide applications and have lower disease levels than in the past. Multi-year data sets have demonstrated local apothecial and plant development monitoring is the key factor for determining when to start fungicide applications. Estimating past and future MVC infection provides information to determine the number and timing of fungicide applications.

Keywords: Monilina, mummy berry, management, weather, forecast

Baseline sensitivity of *Septoria* species associated with lowbush blueberry foliar disease to chlorothalonil and propiconazole fungicides

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Septoria leaf spot and canker diseases caused by *Septoria spp.* are economically important diseases affecting wild blueberry production in Canada. The fungal diseases are responsible for premature loss of leaf area and reducing berry yields. The application of fungicides including chlorothalonil (Bravo®) for control of *Septoria* is common. In addition to this, fungicide applications of the active ingredient propiconazole (Tilt) for other diseases occurring while *Septoria spp.* is sporulating also occurs. To assess the sensitivity of isolates of *Septoria spp.* to these fungicides, a total of 45 isolates of *Septoria spp.* collected in 2009 were evaluated in the laboratory. 21 and 24 isolates of *Septoria spp.* were collected from the blueberry fields near Debert and East River (Guysborough County) Nova Scotia. Baseline sensitivities of isolates of *Septoria spp.* were evaluated by growing fungal isolates in yeast sucrose liquid media in microtiter plate amending different concentrations (0, 0.001, 0.01, 0.1, 1.0, 10 $\mu\text{g mL}^{-1}$) of each fungicide (chlorothalonil and propiconazole). The effective concentration at which the fungal growth is reduced by 50% (EC50) of each isolate for both fungicides were calculated. EC50 values of 45 isolates of *Septoria spp.* for both fungicides varied substantially. EC50 values of these isolates for chlorothalonil ranged from 0.22 to 9.74 $\mu\text{g mL}^{-1}$ with the mean value of 3.1 $\mu\text{g mL}^{-1}$, whereas EC50 values for propiconazole ranged from 0.07 to 15.6 $\mu\text{g mL}^{-1}$ with the mean value of 2.52 $\mu\text{g mL}^{-1}$. About 58% of isolates had EC50 less than 1 $\mu\text{g mL}^{-1}$ for propiconazole, while 20% of the isolates had EC50 between 1 to 5 $\mu\text{g mL}^{-1}$. For chlorothalonil, only 25% of the fungal isolates had EC50 less than 1 $\mu\text{g mL}^{-1}$ and 69% of the isolates had EC50 between 1 to 5 $\mu\text{g mL}^{-1}$ indicating that *Septoria* isolates had reduced sensitivity to chlorothalonil compared to propiconazole.

Keywords: *Septoria*, lowbush blueberry, chlorothalonil, propiconazole

Technical Session #5: Breeding, Genetics, Genomics, and Phenomics

Moderator: Massimo Iorizzo

VacciniumCAP, a community-based project to develop advanced genetic tools to improve fruit quality in blueberry and cranberry

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Vaccinium crops (primarily blueberry and cranberry) provide vital contributions to the U.S. economy and numerous social and health benefits. Although production and consumption of these crops continue to expand worldwide, U.S. Vaccinium industries face numerous challenges to maintain profitability. Stakeholders have asserted that breeding cultivars with improved fruit quality is a high priority for continued success. These traits include fruit firmness, flavor, shelf life, and appearance. Vaccinium breeders routinely select for these traits, however, they have little empirical data to assign a level of importance to specific fruit characteristics (FC) relative to consumer preferences, decay or deterioration during production, processing and distribution. Breeders also possess limited tools to select for a higher quality fruit. The VacciniumCAP project was funded by USDA-NIFA-SCRI to create a nationwide coordinated transdisciplinary research approach to develop marker-assisted selection capacity in Vaccinium breeding programs, and to select for and pyramid FCs, which enhance fruit quality and market value.

The project objectives are to: 1) Establish genomic resources to enable effective association mapping studies in blueberry and cranberry; 2) Discover DNA markers and fruit characteristics that maximize industry profitability and match consumer preferences in blueberry and cranberry; 3) Deliver molecular and genetic resources to improve blueberry and cranberry fruit quality traits Vaccinium stakeholder groups to transfer advanced phenomic and genomic tools to build that maximize industry profitability and match consumer preferences; 4) Assess the potential socio-economic impact of blueberry and cranberry fruit quality improvements on market demand; and 5) Engage U.S. a more efficient cultivar development system. An update on project activities will be presented.

Keywords: Blueberry, cranberry, *Vaccinium spp.*, fruit quality, firmness, metabolites, genetics, genomics, cultivar improvement

Confirming clonal identity: a case study in blueberries

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Horticultural research and industries, including blueberry production, are contingent upon correct cultivar identity. This identity must be maintained by clonal propagation through skilled nursery techniques such as cuttings, grafting, layering, and tissue culture. Breeding, the development of improved cultivars, requires confidence in the identity of parental lines within the gene pool so that continued advancement can achieve planned program goals. Yet, considering human and machine fallibility, errors are inherent in these practices. Hasty production, such as forcing high re-propagation numbers in short timeframes, can increase the number of accidental mis-propagation, mis-labeling, or mis-interpretation events. These errors can reverberate through many generation cycles. The staff at the United States Department of Agriculture (USDA), Agricultural Research Service, National Clonal Germplasm Repository (NCGR) in Corvallis, Oregon, are highly concerned about preserving the correct clonal identity of the diverse blueberry cultivars under their management. Genotypic identity is critical to genebank management and operations. Previously, identity confirmation was determined through the morphology of key taxonomic traits as compared with written descriptions, and visually as determined by expert botanical and horticultural taxonomists. Now, simple sequence repeat (SSR)-based molecular tools have been developed for DNA-based “fingerprinting”. The objectives of this study were to develop a procedural system of cultivar identity confirmation and to suggest consistent ontology. As a discussion example, we present a recent blueberry cultivar identity study of 140 popular blueberry cultivars sampled from three sources. First, fingerprinting-sets of five or 10 tri-nucleotide-containing SSRs were used to genotype the samples. Unique reference fingerprints for each cultivar were established. Parentage analysis, looking at progenitors and progeny, was performed as were comparisons of samples between sources. Genotyping followed by parentage analysis detected correct cultivars, homonyms, synonyms, and incorrect samples. The samples separated into four categories: true to type (TTT) where morphology, SSR markers, and parentage analysis agreed; identity ok (IDOK) where markers agreed but parentage analysis was incomplete; identity question (IDQ) where allele composition did not match parentage and more testing is needed to confirm identity; identity wrong (IDX) where incorrect identity is confirmed by parentage analysis and replacement with TTT is required. In this study, 85% of the 140 NCGR cultivars were TTT or IDOK. The 15% IDQ or IDX will be replaced from original TTT sources. Ideally, with sufficient financial resources, each time a plant is re-propagated, a molecular test that confirms TTT should be performed. We have observed breeder collections with equivalent or greater identity error percentages to that reported here. In summary, molecular markers used in conjunction with parentage analysis, is a strong tool for identity confirmation and should be applied as frequently as re-propagation.

Keywords: *Vaccinium*, genetic diversity, fingerprinting set, microsatellite markers, simple sequence repeat (SSR)

***V. meridionale* hybrids with 4x highbush blueberry**

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The tetraploid blueberry species *V. meridionale* hybridized successfully with 2x and 4x section *Cyanococcus* (blueberry) species. First-generation hybrids with 2x blueberry produced numerous triploids, all essentially sterile. In contrast, first-generation hybrids with 4x blueberry selections are both notably vigorous as well as being significantly pollen fertile. The 4x F₁ hybrids are variable as far as branching structure, dormancy, prolificacy, fruit wax, etc.; however, most appear to be semi- evergreen, with small, darkish fruit. Backcrosses to 4x highbush using the F₁s as females have produced offspring morphologically indistinguishable from 4x highbush at the seedling stage. The F₁ hybrids appear to have potential similar to the early 4x *V. corymbosum* – *V. darrowii* hybrids that gave rise to southern highbush cultivars. The permissive nature of *V. meridionale* germplasm has also made similar hybrids with 4x *V. macrocarpon* possible.

Keywords: *V. corymbosum*, *V. macrocarpon*, cranberry, allotetraploid

Challenges and strategies breeding for firmness, resistance to bruising, and reduced splitting tendency in blueberry in British Columbia

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The blueberry breeding program in British Columbia has identified machine-harvestability for the fresh market as one of its primary goals, and resistance to rain-induced splitting as another high priority. To determine the feasibility of these goals, we studied heritability of susceptibility to rain-induced splitting and examined correlations between splitting tendency and firmness, as well as firmness and susceptibility of fruit to bruising. We have found that in the BC germplasm, splitting tendency had a moderately high narrow-sense heritability (0.61) over a three-year period, indicating the ability to make good gain from selection. Firmness and splitting tendency were not correlated, indicating that selection for firmer fruit can occur concomitantly with selection for reduced splitting with little negative impact. Bruising and firmness were strongly correlated for softer berries, but as the firmness of berries increased through selection, this correlation disappeared. While it is relatively easy to select for firmness in the field, this means that selecting for berries that are less likely to bruise while being mechanically-harvested will require additional steps. We attribute the lack of correlation between firmness and bruising to different mechanisms imparting firmness on the berry that differentially impact bruising of tissues, which are not easily discerned using our current methodologies.

Keywords: Heritability, fruit quality, mechanical harvest

Technical Session #6: Production Systems and Sustainability

Moderator: Alejandro Pannunzio

Water footprint and Life Cycle Assessment as approaches to compare three blueberry varieties and twoways of marketing either bulk or in clamshells

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A study was conducted at a commercial farm from 2010 to 2020 to determine the water footprint and the life cycle assessment for producing blueberries in the Entre Ríos province of Argentina. Three cultivars of southern highbushblueberry (hybrid cross of *Vaccinium sp.*) were evaluated in the study, including 'Star,' 'Emerald,' and 'Snowchaser' and two types of packaging: bulk and clamshells. In each case, plants were irrigated by drip and protected from frost damage using overhead sprinklers. Water requirements for irrigation and frost protection varied among the cultivars due to difference in timing of flowering and fruit development. The average annual water footprint for fruit production in each cultivar are on average 405 L·kg⁻¹ for 'Star', 598 L·kg⁻¹ for 'Emerald' and 835 L·kg⁻¹ for 'Snowchaser' due to different irrigation and water needed for sprinkler systems for frost protection. 'Snowchaser' flowered earlier than the other cultivars and, therefore, needed more water for frost protection. 'Star,' on the other hand, ripened the latest among the cultivars and required little to no water for frost protection. In the case of life cycle assessment for each variety, except the detailed water requirements, are 444 L·kg⁻¹ for blueberries packed in clamshells and 312 L·kg⁻¹ packed in bulk, resulting in 717 and 849 L·kg⁻¹ for Star, 849 and 910 L·kg⁻¹ for Emerald and 1147 and 1279 for 'Snowchaser' in bulk or clamshells respectively, showing the greater water indirect consumption of the use of clamshells instead of bulk, that combined with different varieties gives an enormous range of total water used at farm gate depending on cultivars and types of packaging, giving useful tools to manage and assign water resources.

Keywords: Life cycle assessment, water footprint, irrigation, frost control

Attempts of cultivation of bilberry in a horticultural system

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The European bilberry (*Vaccinium myrtillus*, Ericacea) is a widespread dwarf-shrub in the understory of forests. *V. myrtillus* is mainly distributed in the paleartic Eurasian humid, temperate climate zone from lowlands to altitudes over 3300m, going beyond tree-limit and knee-timber zone. This dwarf-shrub is bound to acidic and humus soils in the understory of species-poor coniferous, mixed and deciduous forests but also forming heathlands in Alpine pastures. Within sunlit to semi-shade forests' edges and on clearings it produces almost every year rich natural yields. Due to its early flowering, it is sensitive to late spring frosts. Bilberry berries are commonly wild- harvested from natural sites, are considered healthy and tasty, and are consumed fresh as well as processed. Domesticating bilberry for regular farming in nurseries or on marginal or remote sites (e.g., after clear cutting) presumably has a potential of creating an additional source of revenue; processing of harvest to medicinal drugs, marmalades, dry fruit and non-alcoholic and alcoholic beverages are even more promising. Soil conditions and mineral nutrients on selected *Vaccinium* stands in Austria were analyzed, natural rooting was investigated and the associated microorganisms in the rhizosphere were determined. Then, from spring 2013 until winter 2015 an experimental trial on the growth-responses of bilberry on growing-media had been conducted on the experimental site Vienna- Jedlersdorf. Two yearold seedlings were acquired from a nursery and put into either commercialized horticultural growing substrates (Sonnenerde torffrei, Kranzinger, Ökohum, peat) or mixtures from peat with added wood chips (spruce or larch tree) or peat inoculated with Rhodovit (Symbiom, CZ) and peat inoculated with extracted and propagated mycorrhiza-fungi from a natural stand ("Am Sailer", Carinthia). The trial was established in three randomly placed replications, three plants per container. Growth parameters of plants were monitored employing non-destructive methods (chlorophyll content, chlorophyll fluorescence, digital picture analysis of top-down photography), substrate analysis (nutrients contents, pH, redox, conductivity, layer depth in the growing-container).

Results show that bilberry can be grown in growing-media for bog-plants, in 'Kranzinger' performing best and interestingly 'sphagnum with spruce' catching up strongly in the last year of the trial, although fruiting appeared to be too weak. We monitored flowering and fruit-setting - but presumably due to the hot and dry summers in the years, plants abscised the unripe fruits. Commercial growing-substrates as well as sphagnum mixtures appeared suitable for cultivation - with the exception of sphagnum with larch-tree wood chips.

Keywords: Vaccinium, dwarf shrub, bog-plant-substrates, root-associated microorganisms, small-fruit-growing, regional added value

Effects of geographic origin and environmental conditions on anthocyanin profile of wild Norwegian lingonberries (*Vaccinium vitis-idaea* L.)

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Lingonberries (*V. vitis-idaea* L.) has received much positive attention due to their exotic taste and high phenolic content. Lingonberries grow across Norway, a country with large variations in climate and topography. The large variations in biotic and abiotic growth conditions has potential to influence quality and availability of lingonberries. A three-year study (2019-2021) with 64 field plots across Norway has therefore been set up, with the aim of studying how genetic adaptations to climate and growth conditions affects chemical composition of the berries. In this poster, anthocyanin content in berries from the first growth season is presented.

Eight locations across Norway (58° to 69°N) with supposed high production potential of lingonberries were selected. Within each location, eight stands (250m²) with different biotic conditions were chosen. Lingonberries were collected from three sectors within each stand. Berries from each sector were lyophilised and extracted with 70% methanol. Phenolic compounds were analysed by HPLC-DAD-MSⁿ, with quantification of anthocyanin at 520 nm and MS used for identification.

The three major anthocyanins in Norwegian lingonberries were cyanidin-galactoside (69-90 %), -glucoside (2-10 %) and -arabinoside (6-23 %). Additionally, small quantities of two other cyanidin glycosides were preliminarily identified. The total content of anthocyanins in lingonberries ranged from approximately 315 to 770 mg/100g dw.

The variation in anthocyanin content, does not appear to be directly linked to latitude, as the variation is as large within the stands of each location as they are between the locations. Results from analysis of berries collected in 2020 and 2021 are necessary to have the basis to draw a conclusion on how biotic and abiotic factors influence anthocyanin content of lingonberries.

Keywords: *Vaccinium vitis-idaea*, lingonberries, anthocyanin, health benefits

Technical Session #7: Production Systems and Sustainability

Moderator: Inger Martinussen

Norwegian wild berries - increased predictability and value creation - the WILDBERRIES project

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Almost 95% of the area in Norway is wilderness and 38% of the land area is covered by woods. These areas are abundant of valuable renewable resources, including wild berries. In our neighbouring countries, Sweden and Finland, wild berries are already a big industry. At the same time, the Norwegian wild berries on the market are almost non-existent and berries are left unexploited.

Lingonberry (*Vaccinium vitis-idaea*) is one of the most abundant and economically important wild berries in the Nordic countries. Nevertheless, lingonberry has a large untapped potential due to its unique health effects and potential for increased value creation. It is estimated that 111 500 tons of lingonberry are produced in the Norwegian woods. Norway is a long and diverse country with a range of climatic conditions. Adaptations to different conditions can give differences in both yield and quality of wild berries. Yields vary enormously from year to year and between different locations. The year-to-year variation in availability is a challenge for commercial exploitation of wild berries. To increase the utilization of berries, there is a need for increased knowledge about availability and quality variation of the berries. A steady supply, predictable volumes and high quality is vital for successful commercialization of wild berries. In addition, the Norwegian market suffers from high labour costs and cannot compete on product price. Innovative solutions and new knowledge on quality aspects can open possibilities for innovation and value creation. To increase possible value creation, the business and innovation potential together with new product opportunities for wild berries should be elucidated.

The main objective in the WILDBERRIES project is to produce R&D based knowledge that will create the basis for increased commercial utilization of Norwegian wild berries

Keywords: Commercialization, lingonberries, *Vaccinium vitis-idaea*, wild berries

The development trend and potential of blueberry industry in China

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Because of China's natural conditions, the level of agriculture development and the practice of blueberry cultivation, the blueberry industry in China is still presently at the preliminary stage of development with the potential for great future prosperity. From North to South China, six growing regions have been preliminarily formed. In the future, the Yangtze River Basin and regions to its south will be the main production areas, and several northern growing regions will gradually develop into mostly protected cultivation areas, and Yunnan province will become a special growing area for fresh fruits due to its unique climatic conditions. Cultural practices adapted to local conditions will be established in each growing area. The application of "soilless culture" and "fertigation" systems could be developed on the local conditions in the future. Based upon the practice of introduction experiments and commercial extensions in the past 35 years, it has been shown that due to the diversity of blueberry varieties, with a serious focus on ecological adaptability, the principle integrating adaptable varieties and suitable orchard site and corresponding cultural practice should be carefully monitored in large-scale cultivation. In the Yangtze River Basin and regions to its south, rabbiteye blueberry cultivation laid the industrial foundation in the early stage of development. With the extension experience in the past 20 years, it has been shown that promising varieties adapted to the large-scale cultivation in southern China could still not be selected from dozens of introduced southern highbush blueberry varieties. It has been approved also that the generation of new varieties with strong adaptability to clay and poor soil, as well as high temperature in summer, must rely on germplasm innovation of blueberry in China. The release of 'Lanmei 1' and other varieties have broken through the bottleneck of the lack of suitable southern highbush blueberry varieties in southern China and laid the foundation for the industrial development. Recently, blueberry growing area worldwide has increased rapidly. Although the fruit supply was not exceeded, the selling price has decreased year by year. Facing this challenge, the blueberry germplasm innovation project should put the target on high fruit anthocyanin content and quality in order to create new varieties possessing the similar function as the wild European bilberry and make the super fruit become the real functional food as shown by 'Lanmei 1'. It could make the blueberry industry more vigorous and economically effective.

Keywords: Blueberry industry, growing regions, China, germplasm innovation, functional food

The Australian story: blueberry production past, present and future

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The Australian blueberry industry was established as a minor industry in the 1980's and has grown substantially over the last 10 years, from 5,500 tonnes of produce in 2014 to over 17,000 tonnes in 2018. This rapid growth is mainly attributed to larger corporate plantings in diverse locations around Australia; new varieties including Australian developed varieties; improved production systems; and greater yields. It has been supported by strong year-on-year sales growth and per capita consumption which is expected to continue.

In 2018, NSW produced approximately 80% of the Australian crop, growing mainly southern highbush varieties as evergreen systems. Since then, plantings in other regions, such as Tasmania and Queensland, have been developed to take advantage of the late and early seasons. This expansion in growing areas within Australia allows year-round production of blueberries of which 90% are consumed fresh domestically while the remaining 10% is exported or processed.

Recently there has been a substantial increase in crop protection methods used including protective tunnels. This, coupled with substrate production, is likely to contribute to further growth in Australian blueberry production.

Amid this growth, the Australian blueberry industry is also facing significant challenges. Prolonged drought, extreme fire and intense rainfall means the industry will need to adapt so that it can still be productive through these challenges.

Current research and development are focused on verifying leaf nutrient standards for blueberry under Australian conditions and describing water and nutrient use by blueberry on a seasonal and growth-stage basis; improving pollination of blueberries under protected coverings; developing export protocols. This is all supported by a good communications program which allows transition of research outcomes into on farm practice.

Keywords: Vaccinium, climate, evergreen, substrate, crop protection, plantings

***Corema album* from the wild to the field**

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Corema album (L.) D. Don a long-lived, dioecious evergreen shrub is native from Atlantic dunes in Iberian Peninsula with white edible berries. The fruits, in addition to their distinctive color and sweet-tasting nature, have a high nutritional value and important characteristics in terms of their polyphenolic composition. As a new berry there is a great interest in the production and marketing of its fruits. Accompanying this growing interest in the species, INIAV initiated the development of a research program with several lines that are underway.

The relation between fruit and seed size is one of the most important selection criteria in this species. Some studies of plant morphology and anatomy, namely flower biology were performed. Being a plant that inhabits dunes with extreme temperature conditions and lack of water in the summer period, it is expected that the germination of their seeds is difficult. Thus, several germination trials have been developed with different types of scarification and stratification with unlike results obtained. In order to understand embryo maturity and seed dormancy, histological sections of embryos were done during the stages of seed and cotyledon development. A germplasm collection from ten origins was established at INIAV Experimental farm at Fataca. To evaluate the phenological behavior of plants from different origins a phenological BBCH scale was proposed. Vegetative propagation tests were also carried out, assessing rooting capacity between different genotype of distinct origins. Genetic diversity assessment based on ISSR markers and agro-morphological traits was assessed in four different sites along the Portuguese coast.

Results show that genetic diversity was higher between populations and lower within. The agro-morphological traits showed high diversity, but not associated to geographic localization.

The opportunity for development of new berry crop presents many potential benefits as well as new challenges. Mass selection of wild plants was performed in 5 Km at Meco coastal dune with special focus on fruit characteristics, mainly fruit and seed size, with the selection of 20 superior clones.

Corema album has great potential as a new berry crop for the coastal region of Portugal. However, more detailed studies for improving agronomic practices are needed.

Keywords: White crowberry; mass selection, seed germination; vegetative propagation; genetic diversity

Technical Session 8: Breeding, Genetics, Genomics and Phenomics

Moderator: Dorrie Main

Using the GDV breeding information management system for efficient management and analysis of breeding data

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Breeding programs produce large amounts of data that require efficient management systems to keep track of cross, performance, pedigree, geographical and image-based data as well as genotyping data. The integration of breeding data with publicly available genomic and genetic data, as well as the integration of each breeder's own genotypic and phenotypic data in a database enhances genetic understanding of important traits and maximizes the marker-assisted breeding utility by breeders and allied scientists. BIMS allows individual breeders to integrate their phenotypic and genotypic data with public genomic and genetic data and at the same time have complete control of their own breeding data and access to tools such as data import/export, data analysis, and data archive. BIMS incorporates the use of the Android App Field Book, open-source software for phones and tablets which allows breeders to replace hard-copy field books, thus alleviating the possibility of transcription errors while providing faster access to the collected data. The use of Field Book and BIMS promotes the use and development of standard trait descriptors and metadata as well. In this presentation, we provide an overview of the Genome Database for Vaccinium (GDV) BIMS and demonstrate new functionality for searching/loading SNP genotype data and haplotype data, cross-search and bulk data editing.

Keywords: Database, VacCAP, software, genetics, genomics, breeding, BIMS, big Data

Breaking interspecific barriers in *Vaccinium*: *V. meridionale* hybrids with blueberry, cranberry, and lingonberry

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The blueberry species *V. meridionale* of section *Pyxothamnus* has shown value as a bridge between taxonomic sections and ploidies in *Vaccinium* as either a first-generation or second-generation parent. Tetraploid *V. meridionale* has hybridized successfully with 2x and 4x species of section *Cyanococcus* (blueberry), 4x section *Oxycoccus* (cranberry) and 2x section *Vitis-idaea* (lingonberry). The first-generation hybrids with 4x blueberry and 4x cranberry both produce strong plants with notable vigor. First generation blueberry hybrids have successfully crossed to both 4x blueberry and 4x cranberry. Second-generation allotetraploid *V. meridionale* - *V. vitis-idaea* hybrids have hybridized successfully with 4x cranberry, 4x blueberry, and 2x lingonberry. It appears that these varied allotetraploid hybrids may allow gene movement among these diverse sections at the 4x level. Further test-crosses are being made to evaluate the range of crossability of 4x *V. corymbodendron* and the hybrid *V. meridionale* allotetraploids with other taxonomic sections of *Ericaceae*.

Keywords: *V. corymbosum*, *V. macrocarpon*, *V. vitis-idaea*, triploid, allotetraploid

Identifying epistatic loci for fruit rot resistance in cranberry using machine learning

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Currently, most marker assisted selection (MAS) methodologies rely on markers developed from either quantitative trait loci (QTL) studies or genome wide association (GWAS) studies. However, there is ongoing research demonstrating that many agriculturally important phenotypes are not conditioned by a single or few loci easily identified using QTL and GWAS methods, but often are the result of combinatorial interacting variants of multiple loci, e.g., epistatic loci. Machine learning (ML) methods offer an alternative means of providing informative markers for genome selection and efficiently predicting interacting and epistatic markers. We have developed methodology that utilizes ML and genotyping by sequencing to provide informative markers for MAS. Our method utilizes genotyping by sequencing data in common vcf format and a boosted regression trees algorithm in an easily obtained Python package. Results were validated in several cranberry families previously studied for low acid traits, where highly associated QTL were identified using the R/qtl software package. In addition, we utilized ML methods to study the polygenic trait of fruit rot resistance in two populations of cranberry that were not well characterized using conventional QTL analysis software. Four major epistatic loci on four different linkage groups were identified in these populations, with three loci contributing up to 23% of phenotypic variance in one population, and two loci contributing up to 27% of the variance in the other population. SNPs at the loci identified facilitated the creation of rhAmp markers for genotyping and seedling screening. These markers are now being validated in subsequent breeding cycles.

Keywords: GWAS, GBS, machine learning, QTL

Heritability of leaf and fruit calcium may enable selection against green fruit drop disorder in highbushblueberry breeding

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Green fruit drop (GFD) is a physiological disorder that manifests in 'Draper' highbush blueberry when grown in several production regions. This condition is related to an acute fruit calcium deficiency, and foliar calcium applications are an effective agronomic solution. However, several cultivars and breeding selections with 'Draper' in their pedigree demonstrate the same tendency for GFD. Therefore, selecting for greater fruit calcium allocation is an important breeding objective. The current study determined narrow-sense heritability of calcium allocation to fruit and leaf tissues in 'Draper' progeny lines to direct future development of marker-assisted selection tools. Leaf and fruit tissue nutrient analyses of 57 selections and cultivars derived from 13 different 'Draper' crosses were collected in 2017, 2018 and 2019 from plants grown in Agassiz, British Columbia, Canada. Narrow-sense heritability was calculated for calcium content as well as the content of several other macro- and micro-nutrients. Trends were interpreted across and between populations derived from the various crosses with 'Draper.' Heritability estimates were low for leaf calcium and moderately high for fruit calcium, varying across years and whether calculations were made of a fresh or dry weight basis for each plant tissue type. Results indicate the potential to effectively select against low fruit calcium and eliminate the tendency for GFD in future breeding lines. Future work includes development of marker assisted selection tools through genetic mapping. This will be of value to several blueberry breeding programs in high chill regions around the world due to the prevalent use of 'Draper' as an excellent parent for several important fruit quality traits.

Keywords: Nutrient content, deficiency, plant breeding, selection, marker-assisted selection, breeding value

Technical Session 9: Breeding, Genetics, Genomics, and Phenomics

Moderator: James Polashock

Cranberry genomics: advances and applications

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Genome sequence data and genetic maps are required to facilitate downstream projects such as enhancing breeding efficiency and identification of key genes of interest. To reduce heterozygosity, we sequenced an inbred, a6th generation self-line progeny, of the cultivar Ben Lear. Short-read Illumina data were coupled with long-read MinION data to assemble a near-chromosome scale genome. Genome annotation was generated using MAKER. Several genetic maps have been generated using SSR and GBS data from populations segregating for traits of interest including the primary target of fruit rot resistance. We have identified four diverse sources of broad-spectrum resistance from our germplasm collection. Crosses integrating putative resistance genes in horticulturally elite genetic backgrounds have resulted in populations segregating for fruit rot resistance and higher productivity. In addition to detecting QTL for disease resistance, we have also identified QTL for yield, fruit epicuticular waxes, and organic acids. We have also detected and characterized reciprocal translocation heterozygotes. Work continues to develop and validate markers to enhance our existing breeding program.

Keywords: Genome, mapping, QTL, disease resistance, next-generation sequencing, fruit quality

Transcriptome analysis of ethylene-regulated ripening in blueberry fruit

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The role of phytohormones in blueberry ripening, especially that of ethylene, is not yet resolved. Climacteric fruits respond to ethylene while non-climacteric fruits respond mainly to abscisic acid. Whether blueberry fruit display a climacteric ripening behavior is not clear. Our data has shown that external applications of ethephon, a plant growth regulator that releases ethylene, and 1-aminocyclopropane-1-carboxylic acid (ACC), an ethylene precursor, accelerate development of ripe fruit in blueberry. Further, blueberry fruit display a peak in carbon dioxide release and ethylene emission during ripening. To further investigate the potential role of ethylene during blueberry fruit ripening, we performed transcriptomic analyses using Illumina sequencing. Fruit from various developmental stages including immature green, green, pink and ripe were used in this study. In addition, differentially expressed genes between ethephon and control (with surfactant) treated fruit were identified and compared with the differential fruit transcriptomes from various developmental and ripening stages. Genes identified as differentially expressed during early and late ripening phases included those associated with hormone biosynthesis and signaling, anthocyanin biosynthesis, and cell wall modification. These genes are likely to play important roles in progression through various phases of ripening. Preliminary analysis indicated that application of ethephon accelerates ripening by increasing transcript abundance of cell wall metabolism-related genes and those associated with negative regulation of ethylene signaling. In comparison to the control treatment, ethephon application down-regulated transcript abundance of photosynthesis-related, and auxin and cytokinin metabolism-related genes. Collectively, results from this study provide fundamental understanding of developmental and ethylene-regulated ripening mechanisms in blueberry fruit.

Keywords: Ethylene, ripening, RNASeq, transcriptome, hormone

Soil and plant-associated microbiomes in *Vaccinium angustifolium* management system

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Wild blueberry fields contain populations of *Vaccinium angustifolium* and *V. myrtilloides*. This provides an attractive system to study plant–microbiome interaction since it involves transformation of the environments surrounding the plant to intensify plant propagation and to improve fruit yield. As a result, the plant genotype and its native location become the only factors that remain unchanged in wild blueberry managed habitats. Consequently, this system is an advantageous model to study the effects of environmental factors on soil and plant-associated microbiomes, the interaction between soil microorganisms and plant–host, and the functional differentiation of rhizosphere microbiomes. The application of both 16S and 18S rRNA amplicon sequencing provided us with understanding of how deterministic factors, such as soil and plant properties shape the wild blueberry microbiome structure and define plant–microbiome interaction. We detected a significant effect of management on the structure of bacterial microbiome in the wild blueberry rhizosphere. Community correlation networks analysis identified several potential hub taxa with important roles in soil fertility and/or plant–microbe interaction and showed that bacterial and eukaryotic interactions became more complex along the soil-endosphere continuum, likely due to the increasing influence of host-plant on microbiome function. We also applied shotgun metagenome sequencing to address the question of a trade-off between microbial adaptation to a plant-influenced environment and its general metabolic capabilities. We identified a niche-specific difference in functions potentially beneficial for microbial survival in the rhizosphere but that might also reduce the ability of microbes to withstand stresses in bulk soils. These functions could provide the microbiome with additional capabilities to respond to environmental fluctuations in the rhizosphere triggered by changes in the composition of root exudates.

Keywords: Soil and plant microbiome, metagenomics, amplicon sequencing

High throughput sequencing aided identification of a novel luteovirus infecting blueberry

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The use of high throughput sequencing (HTS) for virus detection is well documented in many agricultural crops. Several clean plant quarantine facilities for specialty crops such as grapevines, pome and stone fruits have successfully employed HTS as an integral component of their virus detection protocol. In this study, we employed HTS on certified blueberry selections that were previously virus-tested based on the current PCR protocol for virus detection in blueberry. Results of the HTS analysis identified a novel luteovirus in five blueberry selections. The presence of this luteovirus was confirmed by RT-PCR using primers designed from HTS-derived sequences. The full genome of the luteovirus consists of 5,054 nts and most closely related to nectarine stem pitting-associated virus (NSPaV). A survey indicated that the luteovirus is present in other selections and several blueberry growing regions. Additional full genomes revealed 94-99% nt identities to the original isolate. Additional surveys are underway to assess the distribution and population structure of the virus across the country. Overall, these results highlight the ability of HTS to reveal new viruses that are not detected by existing protocols.

Keywords: Luteovirus, blueberry, repeat shock, high throughput sequencing

Technical Session 10: Berry Composition and Postharvest Physiology

Moderator: Sebastian Rivera

Blueberry mechanical properties: Influence of harvest maturity and storage relative humidity

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Blueberry texture is an important quality trait influencing consumers' satisfaction experience. Maturity at harvest and postharvest relative humidity (RH) have been described as sources of variation of mechanical properties during storage. This study aims to determine the influence of harvest maturity and storage relative humidity (RH) on mechanical parameters of cultivar 'Nui' (*Vaccinium corymbosum*). Blueberries were harvested from a commercial orchard located in Hawke's Bay, New Zealand, at three maturities: immature (60-90% blue surface colour), mature (100% blue), and overmature (100% blue and extra seven days on the plant). All berries were harvested at the same time from the same plants and stored for 28 d at 4 °C at five RHs (54%, 75%, 89%, 92%, and 96%). After postharvest storage, the number of "too soft" berries (non-marketable) was measured by hand assessment, and instrumental mechanical parameters were evaluated by texture profile analysis (TPA) and puncture test. Mechanical parameters of hardness (TPA) and force to skin break (puncture test) were lower in overmature berries; meanwhile, the number of "too soft" berries assessed by hand was higher. Storage RH influenced all mechanical parameters except the force to skin break by puncture test. An interaction between harvest maturity and storage RH was observed for TPA parameters of resilience, cohesiveness, springiness, and chewiness. At 96% RH, harvest maturity affected post-storage berry texture, but there were no differences at 54% RH. We concluded that harvest maturity effect on postharvest texture outcomes occur under optimum storage RH, but are less relevant when deficient postharvest RH management occurs.

Keywords: *Vaccinium corymbosum*, Texture Profile Analysis, puncture test

The spatio-temporal accumulation and regulation of anthocyanin in *Vaccinium*

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Vaccinium berries are defined by their colourful appearance and association with health-promoting properties. Berry pigmentation due to the presence of anthocyanin, a type of flavonoid, is integral to fruit appearance and quality, so is a key target for fruit improvement. We took a multi-layer ‘-omics approach to study the molecular mechanism that drives the spatio-temporal accumulation patterns of anthocyanins, integrating metabolomics, genomics, transcriptomics and comparative genomics. We used fruit at different stages of development from two genotypes of different blueberry types, Northern Highbush and Rabbiteye, together with wild bilberry.

Metabolomic analysis of blueberry by Liquid Chromatography–Mass Spectrometry (LC-MS) showed that while metabolite concentrations were comparable between blueberry genotypes when fully ripe, their composition was distinct, indicating that flavonoid biosynthesis was under genetic control. Anthocyanin-derived pigmentation was confined to blueberry fruit skin, while, in contrast, a range of anthocyanins were detected in bilberry flesh as well as the skin. We

detected genotype-specific glycosylation patterns. We further used Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (FT-ICR) mass spectrometry imaging to better understand the spatial distribution of phytochemicals in the fruit as it develops. Results were then contrasted with data obtained by LC-MS. These detailed metabolite maps revealed that anthocyanins and other flavonoids accumulate in highly defined fruit regions of both *Vaccinium* species.

By linking targeted metabolomics with transcriptomics, a common set of genes across the genotypes was identified in addition to genotype-characteristic isoforms. Tissue-specific flavonoid biosynthesis was dependent on co-expression of multiple pathway genes. Candidate transcriptional regulators were co-expressed with genes that encode biosynthetic enzymes, including the activators *MYBA*, *MYBPA1* and *bHLH2*, together with the repressor *MYBC2*, suggesting an interdependent role in anthocyanin regulation. Our study provides new data on the biosynthesis of anthocyanins in *Vaccinium*, which will inform future fruit improvement programmes.

Keywords: *Vaccinium*, blueberry, bilberry, anthocyanin, flavonoid, metabolomics, transcriptomics, MYB, transcription factor.

Investigating the potential of S-ABA to increase anthocyanin biosynthesis in 'Stevens' and 'Howes' cranberry

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Fruit external quality in terms of red color is very important in cranberry (*Vaccinium macrocarpon*) production, as cranberry fruit are harvested based on red color development. Recently, several studies have reported that the foliar application of abscisic acid (S-ABA) induced anthocyanin biosynthesis and improved red color in table grapes. The objective of our study was to test the efficacy of the plant growth regulator S-ABA to improve fruit color in cranberry. The trial was conducted on 'Stevens' and 'Howes' cranberry in East Wareham, Massachusetts USA. Seven treatments were evaluated, an untreated control, single application of 250, 500, 1000 ppm S-ABA at color break and double applications of 250, 500, 1000 ppm S-ABA at color break and halfway between color break and commercial harvest. The treatments were applied with 0.25% (v/v) LI 700 non-ionic surfactant. A randomized complete block design was used with five replications per treatment with buffer rows between treatments and reps. Fruit samples were collected at harvest from each treatment replication and used to measure fruit quality and yield. The application of S-ABA did not improve fruit color as measured by total anthocyanin content in both 'Stevens' and 'Howes' cranberry. Yield, fruit diameter and firmness were not affected by the application of S-ABA. Results on fruit internal quality were inconsistent. Except for the double application of 500 ppm S-ABA, all the treatments had significantly reduced titratable acidity compared to the control in 'Stevens'. No differences in titratable acidity were observed between treatments in 'Howes'. In conclusion, the application of S-ABA with a non-ionic surfactant did not improve fruit color in 'Stevens' and 'Howes' cranberry. The ineffectiveness of S-ABA in cranberry might be explained by surface morphology of the cranberry cuticle which is not very conducive for penetration of sprayed chemicals as reported previously.

Keywords: *Vaccinium macrocarpon*, red color, abscisic acid, fruit quality

Phenolic compound content in blueberry var. Biloxi grown in the Sierra Norte of Oaxaca, Mexico, harvested in warm season

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The objectives of this study were to: (i) understand the behavior of the fruit from the blueberry var. 'Biloxi' planted in a protected system in the San Pedro Nexicho locality, in the Sierra Norte region of the Oaxaca state, Mexico; and (ii) determine the effect of the production-harvest date on the content of bioactive phenolic compounds and their antioxidant capacity in the months of higher temperature (July-October). For this, two cuts were made each month (July-October) in which the temperature varied from 21 to 16 ° C. The results showed that the amount of total phenols in blueberry fruits was directly proportional to the cutting date in the coldest season (307 to 597 mg of gallic acid / 100g of fresh fruit). The anthocyanin content presented significant differences due to the effect of the harvest season, but with a less defined trend (444 to 724 mg of cyanidin / 100g fresh fruit). Conversely, the antioxidant capacity showed significant differences due to the effect of the harvest date, in direct function to the reduction of the production and cut temperatures, with values of 14.2 to 29.7 mg of Trolox equivalent / 100 g of fresh fruit. It is concluded that, in this region of the state of Oaxaca, the highest content of bioactive compounds in fruits produced and harvested in the months of July-October is higher as the fruit cuts are made in the months with lower ambient temperature.

Keywords: Antioxidant capacity, crop conversion, rural development.

Technical Session 11: Germplasm and Propagation

Moderator: Margit Laimer

Germplasm collection of *Vaccinium* species *in vitro*

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Many epidemiological studies confirm that a high consumption of fruit is correlated with a lower incidence of several chronic diseases, mainly for the protective role against cardiovascular, degenerative and proliferative diseases. Therefore, the nutritional quality of fruit today is becoming an attribute as important as the organoleptic- sensorial quality, and breeding and biotechnological approaches are currently used to increase the content of specific bioactive compounds in fruits. The PBU has established over past years a vast collection of *Vaccinium* species from 8 geographic regions (Austria, Azores, Belorussia, Iran, Italy, Madeira, Netherlands, Norway, Slovakia) *in vitro*. These include: *V. angustifolium*, *V. arctostaphylos*, *V. corymbosum*, *V. cylindraceum*, *V. floribundum*, *V. myrtillus*, *V. padifolium* and *V. vitis-idaea*. Donor material was collected from different locations worldwide and consisted of seeds, cuttings or entire plants that were used for tissue culture initiation. Actively growing shoot cultures were initiated according to protocols previously established in the lab, treating every bud like a mericlone.

Plantlets were propagated on WPM and Anderson's medium supplemented with growth regulators and kept at 24°C under 16/8 hrs photoperiod. Separated cultures of each mericlone were produced. This collection serves several purposes in the context of: 1) maintenance of biodiversity, 2) clonal propagation of selected plant lines or cultivars, 3) establishment of transformation protocols, 4) phytosanitary improvement and 5) selection of breeding lines. Viable plant material for replanting to the open field was obtained. Given the fact, that these shrubs have some ornamental potential, the most vigorous clones, beautifully changing foliage coloration in autumn, will be used in an ornamental and forest plant breeding programme.

Keywords: Biodiversity, germplasm storage, phytosanitary improvement, genetic improvement, health-related compounds

A comparison of three culture systems in shoot proliferation of lingonberry

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Micropropagation is an advanced vegetative propagation technology employed to produce a large number of high-quality plants in limited time and space and has been used extensively in *Vaccinium* species. Lingonberry (*Vaccinium vitis-idaea* L.) is a health-promoting fruit crop containing high number of antioxidant properties. To produce the high-quality propagation material, different types of medium and bioreactors are available. However, the effectiveness of the propagation system is not the same for different species. Here we compare the shoot proliferation of two lingonberry clones in a semi-solid medium and two liquid cultures consisting of stationary bioreactor and temporary immersion bioreactor. Shoot regeneration from leaf explants was achieved on an agar gelled semi-solid medium containing 1 mg/L zeatin, keeping 2 weeks in dark and 6 weeks under light. Nodal segments thus obtained were evaluated for shoot proliferation on a semi-solid medium, and in a liquid medium using a stationary bioreactor or temporary immersion bioreactor system after 8 weeks of culture. Shoots per explant and leaves per shoot were counted, shoot height was measured, shoot vigour was scored and hyperhydric plants were expressed in percentage. Liquid media were found to be more effective for shoot proliferation as compared to the semi-solid medium. However, there were differences between the bioreactors in the liquid cultures for some parameters and the effect was genotype-specific.

Keywords: Bioreactor, shoot regeneration, lingonberry, tissue culture

Phytoplasmas in Vaccinium

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Consumer interest in health foods has increased market demand for high quality fruits such as wild and cultivated blueberries. They are used as medicinal plants, due to their high anthocyanin content and are an excellent source of antioxidants. Berries and leaves have various health effects and are used as a disinfectant, to lower cholesterol levels and as treatment for rheumatic diseases.

In vitro techniques like micropropagation are increasingly being used as alternative ways of breeding, for the production of large numbers of plants on a commercial scale, for sanitation purposes and for the maintenance of obligate plant pathogens like viruses and phytoplasmas.

A plant of wild European blueberry (*Vaccinium myrtillus* L.) exhibiting symptoms of shoot proliferation and small leaves was potted in the greenhouse and served as donor material for tissue culture establishment. Infected cultures were maintained over a period of more than 10 years and regularly screened for the presence of phytoplasmas.

Interestingly over a period of several years a phenomenon of spontaneous remission of symptoms occurred, comparable to several cases of fruit trees under *in vivo* conditions described as “recovery.”

A thorough screening by PCR was carried out over several years and revealed that a spontaneous sanitation that occurred during the *in vitro* cultivation process, comparable to – but with a lower extent (percentage) meristem culture and thermotherapy.

Keywords: *Vaccinium* witches' broom, forest plants, molecular detection, micropropagation, spontaneous remission of symptoms

Technical Session #12: Plant Physiology

Moderator: Bernadine Strik

Lessons learned from long-term research on organic production systems of northern highbush blueberry

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Long-term research on organic northern highbush blueberry has been conducted in western Oregon, USA since 2006. Outcomes from trials have had significant impact on organic production in the region. Treatments from 2007–2016 were planting on flat or raised beds, fertilizing with feather meal or fish solubles at a low or high rate (73 and 140 kg·ha⁻¹ N, respectively, at maturity), and mulch [sawdust, yard-debris compost topped with sawdust, or black, woven polyethylene ground cover (weed mat)], in ‘Duke’ and ‘Liberty’. Cumulative yield was 22% greater on raised beds than flat in ‘Liberty’ but was not affected in ‘Duke’. On average, cumulative yield was 4% greater with the low than the high rate of fertilizer and ‘Duke’ produced 35% less yield with fish than feather meal. Mulch had no effect on yield of ‘Duke’, but ‘Liberty’ produced 11% more yield with weed mat than other mulches. Only cultivar affected fruit quality. Weed mat decreased weed management costs by up to 75%, but reduced soil organic matter, and increased irrigation requirement and vole presence. Weed mat has become the most common mulch used in the region. Fertilization with fish and using compost, both containing K, increased leaf K levels reducing yield in ‘Duke.’ Growers adopted using lower rates of fish, improving yield and saving up to \$2000/ha. In 2017, existing weed mat was replaced and added over the existing organic mulches and soy-protein based fertilizer used (only N at 96 kg·ha⁻¹). Stopping use of compost and fertilization with K improved yield in the mature plants by up to 50% over the 4-year study. Adding weed mat over organic mulches improved yield compared to weed mat over bare soil. Yields similar to those of conventional production are possible, however, choice of production system had significant impact on yield, returns, and long-term sustainability.

Keywords: Fertilization, mulch, nutrition, yield, cultivar adaptation

Remote assessment of phenology and Monilinia and Botrytis diseases in wild blueberry fields

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Remote sensing research and development activities were undertaken during the 2019 field season to assess the potential of using the DJI Matrice 600 Pro unmanned aerial vehicle (UAV) and the FieldSpec[®] 3 hyperspectral radiometer to assess plant health, stem growth and development, plant yield and the presence of Monilinia and Botrytis blossom blight diseases. The UAV system was equipped with a 16-megapixel low distortion red, green and blue (RGB) Zenmuse X5 digital camera and a 5-band (blue, green, red, red edge and near-IR bands) multispectral MicaSense camera. The field sites used in the study consisted of commercial fields located at Lemmon Hill and Farmington, and at each site a randomized complete block experimental design with six replications, four treatments and a plot size of 6 x 8 m, with a 2 m buffer between plots. Treatments consisted of (i) an untreated control, (ii) application of Monilinia blight control (Proline™), (iii) application of Botrytis blight control (Luna Tranquility), and (iv) application of Monilinia and Botrytis blight control (Luna Tranquility followed Proline in the fungicide application).

Field level validation was also conducted and spectral signatures of diseased plants, growth stages and disease pressures collected. Assessments of vegetative and floral bud growth stages using the normalized difference vegetation index (NDVI), yield, blueberry coverage and the presence of Monilinia and Botrytis blossom blight diseases occurred. Data was sampled throughout the field season, and ortho-mosaic and digital surface model (DSM) maps generated using the surface-from-motion (SfM) algorithm software. Results indicated that floral and vegetative bud growth and development commenced earlier in *Vaccinium angustifolium* than in *Vaccinium myrtilloides* phenotypes. A range of NDVI values (0.29 – 0.59) provided a good justification of the overall progression of growth and development, and disease assessments over the season. Significant differences were also observed in the spectral response of healthy and diseased tissues. Overall, results have illustrated the potential of using these remote sensing technologies for assessing disease pressures, plant coverage, monitoring growth and estimating yield on wild blueberry fields with a potential of flower and berry detection and plant height determination.

Keywords: UAV, field spectroradiometer, Monilinia blight, Botrytis blossom blight, NDVI

Technical Session 13: Pest Management

Moderator: Philip Fanning

Integrated pest management for spotted wing drosophila in blueberry

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Since its initial detection in North America in 2008, the invasive vinegar fly, spotted wing drosophila, *Drosophila suzukii* Matsumura, has become a serious economic pest for blueberry growers. Facing the risk of *D. suzukii* infestation, most blueberry growers have been using targeted control tactics to avoid infestation, mainly increased insecticide applications. Increases in insecticide usage have had negative impacts, including the development of insecticide resistance, secondary pest outbreaks and increases in the cost of production. These changes in management practices are both economically and environmentally costly and not sustainable. In this presentation, we will explore research aimed at developing integrated pest management programs for *D. suzukii* in blueberry.

Keywords: Integrated pest management, spotted wing drosophila, Attract and Kill, thresholds

Occurrence and population fluctuations of *Drosophila suzukii* (Diptera: Drosophilidae) in blueberry crops of subtropical Argentina

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Argentina exports annually about 10,500,000 kg of blueberries (*Vaccinium corymbosum*), being Tucumán one of the main blueberry producer and exporter province, with 1354 ha, representing 46% of Argentina's blueberry acreage. *Drosophila suzukii* (Diptera: Drosophilidae), commonly known as SWD, is an endemic pest of Southeast Asia that causes significant damage to soft fruit crops. It invaded Argentina in 2014, and the same year it was found infesting blueberry fields in Buenos Aires, from where the dispersion to other provinces began. The objectives of this work was to detect the presence of SWD in blueberry crops in Tucumán and to study its distribution in the main blueberry production areas of the province, during the fruiting season. A survey was carried out in 2015 in a blueberry orchard in Lules department (fruit sampling), and continued from 2016 to 2018 in Lules, Chicligasta and Monteros departments (baited traps). Monteros concentrates the largest Tucumán's blueberry production. Modified McPhail traps baited with apple cider vinegar were set in three conventional blueberry orchards (one, in each department). The samplings were carried out weekly during the blueberry production season, from August to December. The SWD was recorded for the first time in Tucumán in 2015 (Lules). In 2016, it was found also in Monteros and Chicligasta blueberry orchards. SWD adults were found throughout the year, with peak values in December, being lower in Lules (2016: 2.5; 2017: 1.2; 2018: 8.0), intermediate in Chicligasta (2016: 8.6; 2017: 1.6; 2018: 5.4) and higher in Monteros (2016: 3.2; 2017: 2.26; 2018: 8.1). Low abundance in 2017 are associated with lower precipitations. These results confirm the presence and dispersion of the pest throughout the main blueberry growing regions of the Tucumán province. The highest abundance occurred at the end of the fruit exporting season, relativizing the negative impact of the insect.

Keywords: population dynamics, *Vaccinium corymbosum*, SWD, Tucumán

From mitochondrial genome to strobilurin resistance: the history of group I intron evolution in cranberryfruit rot fungi

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The quinone outside inhibitor fungicides (QoIs, also known as strobilurins) are commonly used to control cranberry fruit rot (CFR) caused by fungi. The QoIs represent a group of fungicides with arguably the greatest resistance risk. In 2018, the Fungicide Resistance Action Committee reported more than 50 species with a resistant status to QoIs. Resistance to QoIs is mainly caused by the replacement of Glycine into Alanine (G143A) at position 143 in the target cytochrome b protein. This G143A amino-acid substitution is conferred by a single nucleotide mutation in the cytochrome b gene, hosted in the mitochondrial genome. In fungi, a group I intron, situated directly after codon 143, prevents QoI resistance by blocking the G143A mutation. However, group I introns have the ability to move from a donor gene into an intronless acceptor gene. The mobility of group I introns has been speculated to be a compensation mechanism to restore the potential for QoI resistance mutation. On this basis, a large spectrum *in silico* analysis of whole mitochondrial fungal genomes was performed to characterize the distribution of the group I introns among CFR fungal species. Our results showed that one subtype of group I is associated with QoI resistance and that CFR fungi can be classified according to the presence/absence of this subtype in their genome, resulting in their capacity to acquire the G143A mutation, and thus to become resistant to QoIs. Accordingly, we have developed a model to predict the QoI resistance capacity among CFR fungi and confirmed it with phenotypic validation of the resistance. At a time when the use of synthetic fungicides can lead to resistance and environmental problems, this predictive model could be a valuable tool in managing the use of strobilurins for the purpose of CFR control in cranberry production.

Keywords: Cranberry, group I intron, cytochrome b gene, strobilurins, QoI resistance, G143A mutation, predictive model.

Tine weeding as a weed management tool in Maine wild blueberry

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Eleven percent of the wild blueberry acreage in Maine is certified organic and maximum residue limits (MRLs) reduce the number of herbicides available to growers who sell their berries abroad. There is a need for alternative weed management tactics. This project explored the use of tine weeding as a mechanical weed management option. A flex-tine weeder is a tractor attachment with metal fingers called “tines” that drag through the top half to one inch of soil early in the spring when weeds have just emerged. In a randomized complete block design, tine weeding treatments were executed in May of 2019 and 2020 prune fields at the Blueberry Hill Farm in Jonesboro Maine. Grass and broadleaf weeds in addition to wild blueberry stem density were documented before and after tineweeding. As this was the first tine weeding was done on a wild blueberry field in Maine, some key observations were made. Tine weeding in early May uprooted annual weeds and two tine weeding dates stimulated wild blueberry growth. The June tine weeding date did not reduce weed pressure. Driving on wild blueberry in June clearly damaged the crop more than tine weeding, yet tire tracks filled in visually by August. We know that wild blueberry responds well to mechanical stimulus such as fall pruning, burning, and rhizome disturbance. With further research to fine tune timing and number of passes, tine weeding may be a combination of crop stimulation and weed removal.

Keywords: Lowbush blueberry, tine weeding, organic, weed management

Technical Session 14: Soil Fertility, Plant Physiology, and Plant Nutrition

Moderator: Pedro Brás Oliveira

Extending blueberry production season with different covering materials

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Blueberry production in southwest of Portugal (Alentejo) shows strong interest, due to the possibility of production from April to October, when prices are more favorable. To extend blueberry production season, several types of tunnel covers were tested in Grândola (Alentejo), standard polyethylene to anticipate production and two different nets to delay production. Standard polyethylene was used from bud break to harvest, a white reflective net from fruit-set to harvest, and a silver reflective net throughout the year. The control group had no tunnel cover. These different covers were applied to five varieties, Alix Blue, Gupton, Star (Southern Highbush), Legacy (Northern Highbush) and Skyblue (Rabbiteye). In 5 plants of each cultivar and cover, phenological stages using an adapted BBCH scale, total number of fruits and total fruit weight per plant, average fruit weight, °Brix, average fruit dry matter and new shoot growth were evaluated and radiation under the covers (Photosynthetically Active Radiation, PAR, Photon Flux Density, PFD and the fraction of PAR in total light) was measured using a ceptometer and a spectroradiometer. Results obtained evidenced that average fruit weight and new shoot growth were not significantly affected by the tunnel cover and that all parameters were negatively affected by the permanent silver net, while the white net provided best results for total number (152 fruits) and total weight of fruit (363 g). The polyethylene cover increased mostly fruit dry matter (18.2%). Total PAR, PFD and fraction of PAR in light was mostly reduced by the white net (51%, 54% and less 1.3, respectively), but all the covers showed negative outcomes when compared to the control. Polyethylene was responsible for earlier flowering when compared to a white net (4 days), earlier fruit set (7 days), and an earlier start of fruit ripening (10 days).

Keywords: Photosynthetically Active Radiation, polyethylene, white net, silver net

Better management of soilless growing media for potted Southern highbush blueberry, an Australian case study

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The Australian blueberry industry relies heavily on protected cropping, including using soilless growing media and fertigation for better control of irrigation and fertilisers. The major blueberry production area in Australia is located on the mid-north coast of New South Wales, utilising low chill varieties of rabbiteye (*Vaccinium ashei*) and southern highbush blueberry (*V. corymbosum* interspecific hybrids), grown as evergreen crops. The uptake of soilless systems within this industry has been rapid but the availability of reliable information for using these systems efficiently is very limited. To address this, a trial crop of southern highbush blueberry in two types of soilless media (coir/peat blends) and two pot sizes (35 and 52 litres), and fertigated with an ammonium-containing nutrient recipe, has been established to demonstrate how runoff monitoring techniques can be used to control water and nutrients delivered to the crop, according to plant needs in contrasting conditions (growing medium, pot type, temperature, humidity). Preliminary data is presented to highlight that monitoring of runoff volume, and chemical analyses of runoff and other system components, are appropriate tools for meeting the individualised needs of each soilless crop.

Keywords: Hydroponics, leachate, nutrients, environmental conditions

Fruit transpirational water loss in blueberry is affected by stem scar size and cuticular waxes

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Fruit water loss during postharvest storage is a major concern to blueberry growers and breeders as it affects fruit texture and the sensitivity to pathogens and fungi. Cuticular waxes are part of the cuticle and play an important role in preventing water loss and maintaining firmness in fruits. However, water loss from blueberry occurs both from the cuticle and the stem scar, but detailed correlations between the water loss rate and both the cuticular wax composition and the stem scar size have not been investigated. In this study, cuticular waxes have been characterized in six blueberry varieties (*i.e.*, Duke, Bluecrop, Draper, Calypso, Elliott, and Last Call) during four-week postharvest storage at 0.5 °C and 95% RH. Total wax content at harvest ranged from 40.22 to 79.12 mg/cm² and approximately 80% of the waxes were triterpenoids and diketones in all varieties. Oleanolic acid and ursolic acid were the most abundant wax compounds in all varieties. Total wax content increased during postharvest storage. This increase was mostly due to an increase of triterpenoids. Transpirational water loss has been monitored in the same varieties, under control, stem scar sealing, and wax removal conditions. Stem scar sealing strongly inhibited the transpirational water loss while wax removal showed minor effects. A positive correlation has been observed between stem scar size and transpirational water loss rate. On the other hand, an increased proportion of oleanolic acid was related to a reduced transpirational water loss, whereas an increased proportion of ursolic acid was related to an enhanced water loss. This study provides new insights on factors that affect postharvest transpirational water loss in blueberries with different genetic backgrounds. This knowledge can benefit breeding programs that aim to select new blueberry varieties based on their postharvest performance.

Keywords: Blueberry quality, postharvest storage, triterpenoids, stem scar

Low-input pruning options in 'Mini Blues' for specialized processed markets reduce production costs while maintaining yield and quality

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'Mini Blues,' a small-fruited northern highbush blueberry with uniform, sweet (> 16% soluble solids, 0.8 g/berry), flavorful fruit, is ideal for specialty processed markets and well-suited for machine harvest. Plants are vigorous and produce many small laterals making typical highbush pruning methods time consuming and costly. A planting was established in October 2015 to evaluate pruning options for 'Mini Blues'. Pruning removed all fruit for the first 2 seasons; treatments began prior to the third growing season (2018). Pruning treatments were: 1) conventional highbush pruning (Control); 2) removing one or two of the oldest canes per bush (Speed); 3) unpruned from 2017- 2021; and 4) hedging immediately after fruit harvest starting in summer 2018 (Hedge). In winter 2019-2020, pruning required 423 hr/ha for the control, while speed pruning took 85 hr/ha; the hedge and unpruned treatments required an average of 32 hr/ha to remove low-growing branches that would interfere with machine harvest. Hedging was only done in 2018 because it severely reduced yield; it is not a viable pruning method in this region due to insufficient time for growth and flower bud development after hedging. Harvested yield was not affected by treatment in 2018 or 2020 and was only reduced by hedging in 2019. Berry weight was lower for unpruned plants in 2018 and 2020 compared to the control (0.57 g and 0.73 g, respectively in 2020). Control pruning led to a more concentrated ripening period which would reduce machine harvests needed and cost. However, yield and fruit quality were similar to unpruned and speed pruning and the increase in pruning labor for the control was not enough to compensate for lower harvest costs. We will continue to study these techniques for long-term impacts on yield, quality, and cost of production, particularly the likelihood of needing to renovate unpruned treatment plants.

Keywords: Machine harvest, small fruited cultivar, hedging, northern highbush blueberry, production efficiency

Technical Session 15: Berry Composition and Postharvest Moderator: Charles Forney

Impact of species, growing location and cultivar on flavor chemistry of blueberry fruit

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The flavor chemistry of blueberry fruit, including sugars, organic acids and volatile compounds, was determined in wild lowbush blueberries (*Vaccinium angustifolium*) produced in 4 Canadian provinces and cultivated highbush blueberries (*Vaccinium corymbosum*) representing the 5 commercial cultivars 'Duke', 'Brigitta', 'Jersey', 'Liberty' and 'Aurora'. Sugar and organic acid composition were analysed using high performance liquid chromatography (HPLC) and volatile composition was determined using headspace-solid phase microextraction-2D gas chromatography- mass spectroscopy (HS-SPME-2DGC-MS). In addition, the contribution of volatile compounds to perceived aroma was accessed using gas chromatography-olfactometry (GCO). Fructose and glucose were the primary sugars in both lowbush and highbush blueberries and were present at similar concentrations. Total sugar concentration averaged 16% higher in lowbush than highbush fruit, but varied significantly among highbush cultivars being highest in 'Jersey' and lowest in 'Aurora'. In lowbush fruit, quinic acid was the primary acid comprising on average 66% of the total acids with lesser amounts of citric (23%) and malic (11%) acids. In highbush fruit, citric acid was the primary acid comprising on average 83% of the total acids with lesser amounts of quinic (10%) and malic (6%) acids. Total acid concentration averaged 25% higher in highbush than in lowbush fruit. The sugar:acid ratio of lowbush fruit was higher than that of highbush fruit being 14.1 compared to an average of 9.7 for highbush fruit. However, the sugar:acid ratio of highbush fruit differed among cultivars, ranging from 6.4 to 13.4. The volatile composition of lowbush blueberry fruit was dominated by esters (46%) that provide fruity aromas, and aldehydes (29%) that provide green aromas. Monoterpenoids that provide a variety of floral and fruity aromas comprised only 4% of total volatiles. In contrast, volatile composition of highbush blueberry fruit was dominated by aldehydes (46%) and monoterpenoids (28%), with esters comprising only 4% of total volatiles. Concentrations of sugars, acids and most volatile compounds in lowbush fruit from different provinces did not differ significantly. However, in highbush fruit, sugars, acids and volatiles differed significantly among the 5 cultivars. Compounds identified through GCO analysis that contributed to aroma and flavor of both lowbush and highbush blueberry fruit will be discussed.

Keywords: Sugars, organic acids, volatiles, aroma, quality attributes

HPLC/QTOF validated methodology for the determination of free and bound phenolic compounds in six commercial blueberry varieties

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Blueberries consumption has increased in recent years not only for their attractive flavor and juiciness, but also because of their health benefits. Blueberries are rich in phenolic compounds that play a key role, even at small concentrations, in the prevention of chronic diseases (*e.g.*, type-2 diabetes). Therefore, reliable analyses are essential to select genotypes with superior phenolic contents and profiles. This study aimed to optimize and validate an HPLC/QTOF methodology for the analysis of 39 phenolics, comprising anthocyanins, flavonols, flavan-3-ols, and phenolic acids, in blueberries. A gradient of 2% formic acid in water and 0.1% formic acid in acetonitrile using a C18 column allowed the separation of the 39 compounds in 10 minutes. Their simultaneous detection in positive electrospray ionization was confirmed using MS/MS fragmentations. Extraction efficiencies higher than 85%, good linearities ($R^2 > 0.9990$), and suitable reproducibilities (RSD < 15%) were reached for free phenolics using acidified 80% methanol and 65% acetone extractions followed by a clean-up solid-phase extraction (SPE) step. Matrix effects were corrected for an accurate quantification of free phenolics. Bound phenolics were extracted with an overnight hydrolysis in 10% sulfuric acid (in methanol) at 85 °C, adjusting the pH to 4.5 and removing the generated salts using SPE. The method feasibility was evaluated analyzing free and bound phenolics in 6 commercial blueberry cultivars (*i.e.*, Duke, Draper, Bluecrop, Calypso, Elliott, and Last Call) collected in British Columbia (Canada) at commercial harvest. Phenolic profiles and contents were highly dependent on the blueberry variety, presenting 'Elliott' the highest concentration of almost all the free and bound phenolics. Generally, malvidin-3-O-galactoside was the most abundant free phenolic among all varieties (885-156 mg/Kg FW), followed by delphinidin-3-O-galactoside, and/or chlorogenic acid. Traces of flavonol glycosides and catechin were also found. Chlorogenic acid was the major bound phenolic among the 6 blueberry cultivars.

Keywords: Free phenolics, bound phenolics, liquid chromatography-mass spectrometry, validation, blueberry, commercial varieties

Investigating ethylene-regulated changes in metabolite composition during the blueberry (*Vaccinium spp.*) fruit ripening

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Fruit ripening is the final stage in fruit development where coordinated molecular and metabolic changes render the fruit attractive and palatable. These changes include conversion of starch to sugar, pigment accumulation, changes in cell wall metabolism, and production of volatile compounds. Blueberry (*Vaccinium spp.*) fruit display a rise in ethylene during fruit ripening, however ethylene levels vary among cultivars. Also, application of ethephon and 1-aminocyclopropane 1-carboxylic acid (ACC), ethylene releasing plant growth regulators (PGRs), can promote ripening by increasing the proportion of blue fruit in blueberry. The objective of this study was: 1) to compare metabolite changes between two cultivars, 'Premier' and 'Powderblue,' that differ in ethylene levels during ripening 2) to identify ethylene regulated metabolite changes during the ripening after application of ethylene releasing plant growth regulators (PGRs). For objective 1, we collected fruit samples from five different developmental stages, including ripening based on size and color, from the Durham Horticulture Farm, University of Georgia, Watkinsville, GA. The cultivar 'Premier' produces higher ethylene levels compared to 'Powderblue.' For objective 2, three treatments were applied: 250 ppm of ethephon, 250 ppm of ACC and control. Samples were randomly collected at 0, 3, and 5 days after treatment (DAT) and consisted of fruit from several developmental stages. Ripe fruits were also collected at 10 DAT from all three treatments. Metabolite analysis was performed using gas-chromatography. Preliminary analyses indicated that the concentration of glucose, fructose, sucrose and myo-inositol increased as ripening progressed, whereas malic acid and quinic acid decreased in both cultivars. Comparison among cultivars indicated higher concentration of malic acid, aspartic acid, and glutamic acid in the 'Premier,' whereas citric acid, quinic acid, and myo-inositol were higher in 'Powderblue.' Application of ethylene releasing PGRs, decreased malic acid and increased aspartic acid and glutamic acid concentration at 3-5 days after application. At 10 DAT, application of PGRs reduced glucose, fructose and sucrose concentration in Powderblue. Results from this study suggests differences in metabolite composition between blueberry cultivars. Further, ethylene regulates sugar and acid metabolism during blueberry ripening.

Keywords: Sugar, organic acid, ethylene, ripening

Technical Session 16: Soil Fertility, Plant Physiology, Plant Nutrition Moderator: David Bryla

Beneficial use of biostimulants in northern highbush blueberry

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Many growers are using biostimulants such as humic substances and natural extracts from seaweed in an effort to improve plant growth and production in their crops. These products are typically used as foliar or soil supplements and often work best when applied with fertilizers. Previously, we discovered that application of humic substances increased plant growth during the first two years after planting in 'Draper' blueberry (*Vaccinium corymbosum* L.).

The effects on root growth were particularly apparent and resulted in 46-75% greater root dry weight than either conventional fertigation, granular fertilizers, slow-release fertilizers, or a control treatment that lacked humic substances but contained exactly the same nutrients. A trial was then conducted in a mature planting of 'Bluecrop' blueberry. In this case, humic substances increased root growth and the availability of P and Zn in the soil relative to controls with fertilizer only, but after three years, they had no effect on shoot growth, yield, or fruit quality. Next, we tested several different biostimulants, including humic substances, extracts from *Ascophyllum* seaweed, and a mix of N-fixing *Azospirillum* bacteria, on potted plants of 'Draper' blueberry. Fertigating with humic substances or seaweed extract increased growth of the plants relative to using the bacterial mix or nutrients only; however, the response was quite different between the two products. Plants grown with humic substances were greener and contained more N than those in the other treatments, while those grown with seaweed extract tended to be taller and more upright. Clearly, the use of these products can be beneficial during establishment of highbush blueberry, but more research is needed to determine exactly how they work and whether they are useful under all circumstances.

Keywords: Fertilizer, humic substances, plant growth promoting bacteria, seaweed extract, *Vaccinium corymbosum*

Response of northern highbush blueberry to fertigation and granular applications of phosphorus fertilizer

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Previous studies indicated that fertigating with N was more effective than using granular N fertilizers in northern highbush blueberry (*Vaccinium corymbosum* L.). The objective of the present study was to build on these findings and determine whether fertigation was also an effective method for applying P. The trial was located in Oregon, USA and conducted in a mature planting of 'Duke' and 'Bluecrop' blueberry. Treatments were applied for 2 years to both cultivars and included no P, a single application of P fertilizer in the spring (early April) using granular monoammonium phosphate (MAP) at the highest recommended rate of $67 \text{ kg}\cdot\text{ha}^{-1} \text{ P}_2\text{O}_5$, and weekly fertigation from mid-April to late-July with liquid ammonium polyphosphate at a total rate of 34 or $67 \text{ kg}\cdot\text{ha}^{-1} \text{ P}_2\text{O}_5$ per year.

Each treatment was also fertigated with $150 \text{ kg}\cdot\text{ha}^{-1} \text{ N}$ and $1.8 \text{ kg}\cdot\text{ha}^{-1} \text{ B}$ per year. In the year prior to applying the treatments, the concentration of P in recently expanded leaves was low in both cultivars (0.08-0.09%) and below the recommended level for blueberry in the region ($> 0.10\%$). Both fertigation and granular fertilizer application increased the concentration of P in soil solution within the root zone, but neither had any effect on yield, berry weight, or berry firmness during the study in either cultivar. These treatments also had no effect on leaf P. In fact, the concentration of P in the leaves was no different than it was prior to applying any P. The soil at the site was high in clay (Malabon series) and likely bound much of the P applied as fertilizer. Similar results were found in grower fields in Oregon. Questions remain on whether blueberry requires less P than recommended or if alternative sources or rates of P fertilizer are needed.

Keywords: Fertigation, foliar fertilizer, micronutrients, plant nutrition, *Vaccinium corymbosum*

Fall nitrogen fertilization in cranberry: effects on plant growth and fruit production

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New research on cranberry plant development has shown that the early to mid-dormant period is key for flower primordia differentiation and new root production, factors which determine yield potential for the following season. The objective of this research is to evaluate the effect of fall nitrogen fertilization on cranberry vine vegetative growth, as well as fruit yield and quality. Two fertilization schemes were established on three 'HyRed' cranberry beds at a farm in central Wisconsin. Initially in Fall 2017, plots received 0, 10, 20 and 40% of the next season's projected total nitrogen application (60 N units). During the 2018 growing season, the second scheme was initiated by dividing each previously established plot into two subplots. Over multiple application times, one subplot received the balance of N units based on the Fall 2017 application, while the other received a total of 60 N units in addition to the initial Fall 2017 application. During the 2018 and 2019 growing seasons, plant responses to these two schemes were evaluated for total yield, fruit number, color, firmness, and size, as well as total vegetative growth and upright length. There were no significant differences among treatments for yield, fruit firmness, size, or color. Treatment differences were found for berry weight and vegetative biomass production.

Keywords: Cranberry, fall fertilization, nitrogen, fruit quality, plant growth, *Vaccinium macrocarpon*

Relationship between fruit firmness and dry matter of three blueberry cultivars (*Vaccinium corymbosum* L.) in different agroclimatic zones in Chile

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The berry market is highly competitive, and Chilean fruit must travel long distances to reach its destination with high quality, such as size and color, and condition requirements, such as firmness (F), dry matter (DM), titratable acidity (TA), and soluble solids (SS). Exporters usually use DM content as the principal firmness indicator. The objective of the present study was to determine the relationship between F and DM, and F and SS in three blueberry (*Vaccinium corymbosum* L.) (Brigitta, Legacy, and Elliott) cultivars in three agroclimatic zones (foothills, central valley, and coastal drylands) in the Ñuble Region, Chile. The 100% blue color of the berries was used as the harvest index. Berries were taken to the laboratory to evaluate fruit weight, diameter, DM (%), TA, SS, and F. A correlation was made between F and DM and between F and SS with a linear regression. Results indicated that all evaluated parameters varied according to the agroclimatic zone. Both F and DM exhibited a negative correlation coefficient, which indicated an inverse relationship. The linear regression showed R^2 values between 0% and 29% according to the cultivar and agroclimatic zone; similarly, the correlation and linear regression between F and SS had values between 0% and 19%. Given these results, DM and SS content are not adequate variables to define F, which is usually determined by the cultivar and agroclimatic zone in which it is cultivated.

Keywords: Blueberry, fruit firmness, dry matter, *Vaccinium corymbosum*

**POSTER ABSTRACTS
LISTED IN ORDER OF PRESENTATION**

Session 1: Breeding Genetics and Phenomics

P1: Development of an ultra-density linkage map and QTL mapping for fruit quality traits in blueberry (*Vaccinium corymbosum* L.)

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Blueberries are a rich source of health-promoting phytochemicals, which have in part contributed to a rapid increase in consumer demand and production over the past 15 years. Developing strategies that can increase the blueberry production and that meet consumer preferences will be critical for sustaining the consumption growth. Studying how blueberries nutritional and quality traits are genetically regulated, and association between fruit quality traits and metabolites is an essential step towards improving genomics-assisted breeding programs in this crop. In this study, we present a high-density linkage map and unravel the underlying genetic basis of fruit quality (FQ) traits including titratable acidity (TA), pH, total soluble solids (TSS) and fruit weight (FW) in blueberry. A total of 287 F1 individuals derived from a cross between two southern highbush blueberry cultivars, Reveille and Arlen, were phenotyped over three years (2016-2018) for FQ related traits. A total of 17k single nucleotide polymorphism (SNP) markers were used to construct ultra-dense linkage map that spanned a total 1,397 cM with an average inter-loci distance of 0.08 cM. Quantitative trait loci (QTL) mapping revealed a total of 18 significant QTLs including 7 QTLs for FW, 3 QTLs for TA, 5 QTLs for pH, and 3 QTLs for TSS. These QTLs explained phenotypic variance ranging from 7% to 28% for TA and TSS, and 8% to 13% for pH. The study also established the correlation between FQ traits and metabolites detected by ¹H NMR analysis directly responsible for these FQ traits. A

significant ($P < 0.05$) and positive correlation was observed between organic acids (citric acid, and quinic acid) and TA. As expected, sugar molecules exhibited a significant ($P < 0.05$) and positive correlation with TSS. Overall, the study provides an insight into the genetic basis of FQ traits, and association between FQ traits and metabolites.

Keywords: High-density linkage map, QTL, organic acid, sugars.

P2: Evidence of a reciprocal heterozygous translocation in cranberry

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Pollen tetrad analysis of a fruit rot resistant germplasm accession, US89-3, indicated the presence of heterozygosity for a reciprocal translocation, prompting a marker investigation of the translocated regions. Reciprocal heterozygous translocations maintain heterozygosity in interstitial regions upon inbreeding. The segregation of markers (SNPs) within a US89-3 x Crimson Queen progeny population were analyzed using genotyping-by-sequencing. Contrasting the genetic maps of families derived from US89-3 to those lacking the US89-3 parental background revealed that US89-3 contained a genetic interchange between LG5 and LG6. In cranberry, the four resulting gametes (pollen) of microgametogenesis are shed as a tetrad. Tetrad pollen viability analysis revealed a trimodal distribution of 4's, 2's and 0's classes resulting from genetic imbalance when cross-overs occur interstitially between the centromere and the translocation event in individuals heterozygous for the translocation. Whole genome sequencing using Illumina paired end reads and alignment to an updated cranberry reference genome (487Mb, 124 contigs, N50 15Mb) was performed to better locate the translocation breakpoints in US89-3. GROM was used to identify potential translocation events in the NGS data. Four unique reciprocal heterozygous translocations were identified in NGS data between LG5 and LG6. De novo assembly of LG5 and LG6 returned evidence of continuity across these breakpoints. Continuity was validated through PCR, where complete PCR products were produced across the breakpoints of LG5 and LG6 in individuals carrying the translocation. There were no predicted genes identified crossing these translocation breakpoints, however eight gene fragments were found within 1kb in each direction of breakpoints. Targeted sequencing is currently being performed across the translocation breakpoints to better map the region and clarify the genomic effect of the translocation event.

Keywords: Translocation, pollen abortion

P3: Wild blueberry phenotypes infected with *Monilinia vaccinii-corymbosi* have varied PR gene responses under field conditions

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Monilinia vaccinii-corymbosi (Reade) Honey (*M.vc*), the causal agent of Monilinia blight, is a damaging disease on wild blueberry fields. Variations in Monilinia blight levels among wild blueberry phenotypes from the same environment suggests that host genes play a role in controlling disease severity. To determine whether the phenotypes differed in response to *M.vc*, the expression pattern of pathogenesis -related genes (PR3 and PR4) were evaluated in the wild blueberry phenotypes *V. angustifolium*, *V. a. f. nigrum* and *V. myrtilloides*. A spore suspension of (2×10^5 conidia-ml⁻¹) was applied to floral buds at F3 stage and floral buds were collected at days 0, 3, 6 and 10 under field conditions. At 10 days post inoculation, *V. myrtilloides* exhibited minimal disease symptoms, whereas the entire *V. a. f. nigrum* appeared to be wilted and covered with grayish masses of conidiophores. *V. angustifolium* also exhibited disease incidence but not as accelerated as *V. a. f. nigrum*.

Expression analysis (qPCR assay) revealed that PR3 and PR4 genes exhibited considerable upregulation in *V. myrtilloides* and *V. angustifolium*. VmPR4 have an increased expression at all timepoints than VaPR4. On the contrary, *V. a. f. nigrum* failed to activate PR4 expression despite being able to perceive the fungus. VmPR3 exhibited no expression at day 0 then the induction increased gradually and reached more than two-fold on day 10. However, VaPR3 had a peak expression at day 0, and then exhibited an intermittent expression for the other timepoints. VnPR3 expression in *V. a. f. nigrum* were exiguous, suggesting a very weak response. Altogether, the study indicates that the degree of phenotype susceptibility is associated with the activation of host defense responses. The results reported herein help in understanding the complex wild blueberry-Monilinia pathosystem and may possibly aid in defining future strategies for best plant health measures.

Keywords: Wild blueberry, *Vaccinium angustifolium*, *Vaccinium myrtilloides*, Monilina blight, gene expression, pathogenesis- related proteins

P4: Screening of southern highbush blueberry breeding population for parthenocarpic ability and fruit quality characteristics

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Parthenocarpy in blueberry could provide a more economical and effective method of ensuring fruit set than the traditional reliance on honey bees. Florida blueberry producers rent bee hives every season to achieve sufficient yield. A drawback of this method is that honey bees are less efficient at pollinating blueberry flowers than native bee species. In addition, poor weather conditions during flower bloom can significantly reduce bee-foraging activity.

Moreover, the worldwide decline of honey bee populations is a serious threat to several crops. In this scenario, parthenocarpy (i.e., the fruit formation without fertilization or pollination) could provide a low input alternative to save producers investments and secure profitable fruit set. Therefore, the objective of this study is to screen the University of Florida (UF) Southern Highbush Blueberry breeding population for parthenocarpy and to evaluate fruit quality characteristics of seedless berries. We compared seeded and seedless fruits in terms of firmness, size, Brix, pH, and Total Titratable Acids (TTA). From the population screening, we selected cuttings of 15 genotypes, which were placed in three replicates in a greenhouse and in a high tunnel setting. The plants were covered with a net to avoid pollinators. All ripe berries were harvested and evaluated for presence of seeds and a subset for fruit quality characteristics. These comparisons will provide a preliminary result about the potential sources of parthenocarpy to develop new blueberry cultivars.

Keywords: *Vaccinium spp.*, pollination

P5: Environmental regulations on flowering and expression of flowering genes in southern highbush blueberry

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Flowers of blueberry are generally induced by cool temperature with short-day conditions in autumn and bloom in spring. However, cultivars such as 'Blue Muffin' show a perpetual blooming behavior and varied flowering seasons between plants cultivated in temperate and subtropical climates. To document the temperature and photoperiod effects on blooming and expression of flowering genes, 'Blue Muffin' (BM), 'Sunshine Blue' (SB), and 'Georgia Gem' (GG) southern highbush blueberries were cultivated in phytotrons with day/night temperatures of 35/30°C, 25/20°C, or 20/15°C and nature photoperiods of Taipei, Taiwan (25.03° N) from April to December 2020. Flowering status and expression of the flowering promoter gene FLOWERING LOCUS T (VcFT) and flowering suppressor gene VcConstans-like (Vc COL) were analyzed in a three-week interval. Flowering occurred in BM through the experiment period regardless of temperature and daylength while flowering in SB and GG occurred only at mild (25/20°C) and cool (20/15°C) temperatures after mid-summer. At 35/30°C, the expression of VcFT was suppressed in all three cultivars while the expression of COL was upregulated but usually lower in BM than in SB and GG. Flowers were observed in SB and GG grown at 25/20°C in early October when daylength < 12 hours, while flowers in both cultivars at 20/15°C were observed in August when daylength was close to 13 hours. The expression level of VcFT was low in all three cultivars subjected to either mild or cool temperatures from May to August then elevated thereafter. The results suggested that the expression of both VcFT and COL, and VcFT sensitivity to photoperiod, were both suppressed by high temperature while the expression of COL in 'BM' appeared less responsive to high temperature, contributing to the perpetual flowering of this cultivar.

Keywords: Temperature, perpetual flowering, photoperiod, VcFT, Vc COL.

P6: Confirming identity of blueberry cultivars with a microsatellite fingerprinting set

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The United States Department of Agriculture Agricultural Research Service National Clonal Germplasm Repository (USDA-ARS NCGR) in Corvallis, Oregon preserves more than 1,800 *Vaccinium* L. accessions represented by 83 *Vaccinium* taxa from 34 countries. Confirming the genotypic identity of blueberry cultivars in the NCGR collection is critical for effective genebank management. A 10-SSR fingerprinting set of tri-nucleotide-containing-SSRs in blueberry was previously applied together with parentage analysis to confirm identity in 297 plants representing 143 unique accessions from the NCGR collection. Four categories of plants were observed and they include: true-to-type (TTT) where morphology, SSR markers, and parentage analysis agreed; identity ok (IDOK) where a unique genotype was achieved in multiple plants from different sources but parentage analysis was insufficient; identity question (IDQ) where allele composition was not compatible with parentage and more analysis is needed to confirm identity; and identity wrong (IDX) where inaccurate identity is confirmed by parentage analysis and replacement with TTT is needed. The objective of this study was to confirm the identity of accessions in the IDOK (7) and IDQ (13) categories, replace accessions in the IDX (2) category with TTT genotypes, and create baseline fingerprints for the remaining cultivated blueberries (46) in the NCGR collection. One hundred and twenty-nine samples representing 91 unique accessions were genotyped with the 10-SSR set. Plants for each of the accessions in the IDOK, IDQ, and IDX categories were obtained from two to five sources such as breeder collections and private nurseries. Parentage analysis using TTT parents or offspring will confirm the identities of these cultivars and will be presented. This study will enable a protocol that can ensure clonal identity of the blueberry cultivars in the NCGR collection.

Keywords: Blueberry, microsatellite markers, simple sequence repeat (SSR)

P7: Identification of candidate abiotic stress tolerance loci in wild cranberry using environmental association

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Populations of crop wild relatives may become adapted to local climatic conditions through natural selection. Understanding the genetic basis of this local adaptation in wild relatives could help inform breeding decisions for incorporating favorable alleles influencing abiotic stress tolerance into cultivated germplasm. One approach to this is environmental association, whereby genomewide molecular markers are tested for their association with the local climatic conditions of natural populations. In this study, we conducted an environmental association analysis in an established collection of 114 wild cranberry (*Vaccinium macrocarpon* Ait.) accessions sampled from 16 diverse locations and genotyped with 4,412 SNP markers. We detected several loci with putative roles in adaptation to local temperature (11 markers) and precipitation (23 markers) conditions. These genomic regions may contain favorable alleles for tolerance to heat, cold, or water availability stresses. The potentially adaptive loci identified in this study may facilitate a more targeted use of wild cranberry germplasm to improve abiotic stress tolerance in cultivar development.

Keywords: Cranberry, environmental association, local adaptation, abiotic stress tolerance, gene-environment interaction

P8: Lessons learned from 30 years of evaluating northern highbush blueberry genotypes ' the importance of rotating plantings and using commercial production methods

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From 1990–1993, Oregon State University (OSU) evaluated genotypes from blueberry breeding programs in the USA to determine adaptation to Oregon. From 1993-present, this became part of the USDA-ARS/OSU Cooperative Program, expanding to include breeding new cultivars for the northwest. Over 350 genotypes have been evaluated at the North Willamette Research and Extension Center. In 1990 the 0.4-ha-trial was established using standard practices (amendment with sawdust, 1.2 x 3 m spacing, flat ground, sprinkler irrigation); the design was completely randomized with five replications of three-plant plots per 40 genotypes. Bird control netting was installed to accurately assess yield. Results showed three replications and harvesting in years 4–6 were sufficient to detect meaningful differences. Good performing advanced selections were released or co-released ('Norman', 'Pink Champagne', 'Pink Lemonade', 'Chandler', 'Perpetua', 'Echo', 'Mini Blues') and removed along with poor performing ones. New genotypes were added with three replicates. To change with the industry, sawdust mulch was added (late 1990s), then weed mat (mid-2000s), and irrigation was switched to drip (early 2000s); however, fertigation was not possible. Plant performance declined after 2000, likely from replanting issues – over time the in-row area became depressed (soil loss) and compacted. In 2017 we transitioned to a new location. Genotypes are added in multiples of entire rows (three reps) with sawdust amendment, raised beds, drip irrigation, and weed mat mulch.

Plants are fertigated and pruned annually in winter with first fruit in year 2 (observation) and yield collected in years 3–5. A green laser is used for bird control. Using standard commercial practices and designing plantings so rows can be properly prepared are critical to achieve representative growth and yield. Two genotypes are slated for release as ornamentals (ORUS 285-1; ORUS 285-2). Results of promising advanced selections will be presented.

Keywords: *Vaccinium corymbosum*, breeding, cultivar evaluation, selection trials

P9: High density genetic linkage map and identification of QTL for chilling requirement, cold hardiness, and fruit quality traits in a diploid blueberry population

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Genotyping by sequencing approaches have been widely applied in major crops and are now being used in horticultural crops like berries and fruit trees. We previously constructed an interspecific mapping population of diploid blueberry by crossing the parent F1#10 (*Vaccinium darrowii* Fla4B × diploid *V. corymbosum* W85-20) with the parent W85-23 (diploid *V. corymbosum*). Employing the Capture-Seq technology developed by RAPiD Genomics, with an emphasis on probes designed in predicted gene regions, 117 progeny, the two parents, and two grandparents of this population were sequenced, yielding 116.6 Gbp raw sequenced reads. A total of 160,535 single nucleotide polymorphisms (SNPs), referenced to 4,522 blueberry genome sequence scaffolds, were identified and subjected to a parent-dependent sliding window approach to genotype the population. Recombination breakpoints were determined and marker bins were deduced to construct a high-density linkage map. Twelve blueberry linkage groups (LGs) consisting of 17,486 SNPs were obtained, spanning a total genetic distance of 1539.4 cM. Among 18 horticultural traits phenotyped in this population, quantitative trait loci (QTL) that were significant over at least two years were identified for chilling requirement, cold hardiness, and fruit quality traits of color, scar size, and firmness. In one year, a QTL associated with timing of early bloom, full bloom, petal fall, and early green fruit was identified in the same region harboring the major QTL for chilling requirement. In summary, we report here the first high density genetic linkage map of our diploid blueberry mapping population and the identification of several horticulturally important QTL.

Keywords: *Vaccinium*, plant development, quantitative trait loci, single nucleotide polymorphisms

P10: A high-throughput phenotyping method using near infrared spectroscopy to measure anthocyanin content in blueberry

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Blueberries (*Vaccinium sp.*) are well recognized as a health-promoting fruit due to the phytochemical components of anthocyanins. However, little is known about the underlying genetic components controlling anthocyanins in blueberries. This could facilitate the development of blueberry cultivars with increased anthocyanin content or specific anthocyanins. Total anthocyanin content (TAC) is typically quantified using high-performance liquid chromatography (HPLC) which is expensive and time consuming. Phenotyping anthocyanins for genetic studies requires hundreds to thousands of samples. Therefore, it is necessary to develop a method that is more high-throughput.

We investigated the utility of near infrared spectroscopy (NIR) to predict the quantity of TAC in blueberries. 57 diverse blueberry genotypes were harvested over two years and quantified for TAC using HPLC and spectra were collected using a Perten DA 7250 NIR. Two sampling methods were used, freeze-dried blueberries and freeze-dried skins of blueberries. Samples were scanned in the reflectance mode in the wavelength range of 950-1650 nm with 141 data points per sample spectrum collected. Calibration models were constructed for the whole berry and skin-only samples using the Unscrambler package and Honigs regression to calculate the correlation between NIR spectra and HPLC data. The calibration curves were validated in the skin-only samples and whole berry samples using 162 and 167 genotypes, respectively. A comparison of the observed (HPLC) and predicted (NIR) values in the calibration dataset revealed that the model accounted for 83% of the observed variation in TAC (ug/mg dry weight (DW) for skin-only and 93% for the whole berry method. In the skin-only samples, the only groups of anthocyanins which could be predicted were delphinidin-, petunidin- and malvidin-based anthocyanins. The NIR prediction for TAC was more accurate in the whole berry samples. Our results demonstrate that NIR can be used as a high-throughput method to predict TAC in blueberries.

Keywords: Blueberry, *Vaccinium*, HPLC, anthocyanin, near infrared spectrophotometer, high throughput phenotyping

P11: Molecular responses of wild blueberry phenotypes to *Botrytis cinerea* infection

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Botrytis blight is an important disease of wild blueberry which causes approximately 20% yield loss annually. Botrytis damage is often variable throughout commercial wild blueberry fields due to varying levels of genotypic resistance among wild blueberry clones. However, the molecular basis of the plant response to this pathogen is yet to be elucidated. This study was conducted to investigate the defense response, and changes in flavonoid and jasmonate pathway genes associated with *B. cinerea* infection. Six phenotypes (*Va* brown, *Va* green, *Va f. nigrum* and *Vm*, tall, medium and short) inoculated with *B. cinerea* under field conditions. Samples were harvested at 0, 12, 24 and 48 hrs post inoculation (hpi) and evaluated for their molecular response with qRT-PCR. The induction of pathogenesis-related genes was observed to be early (12 hpi) in *Va* phenotypes. Maximum expression levels of PR-4 were observed at 12 hpi while PR- was delayed to 24 hpi. Induction of PR genes was remarkably high and early in *Va f. nigrum*. Short and medium stem *Vm* showed similar pattern in as *Va* however, PR-4 was on a steady rise in short stem up 48 hpi. PR genes were down regulated in tall stem *Vm*. Jasmonate genes were activated in all the phenotype. Maximum levels were seen at 24 hpi in most of the phenotypes with *Vm* indicating more expression. All flavonoid genes tested were mostly suppressed in the early stages followed by up regulation to reach maximum levels at 24 and 48 hpi. These results suggested PR genes especially, PR-4 might play an important role in the defence of wild blueberry against *B. cinerea* compared to other stress related genes. This study may provide a starting point for achieving a better understanding of the Wild Blueberry-*B. cinerea* pathosystem.

Keywords: Wild blueberry, *Vaccinium angustifolium*, *Vaccinium myrtilloides*, *Botrytis cinerea*, real-time RT-PCR, gene expression

P12: Assessment of rabbiteye blueberry (*Vaccinium ashei*) cultivars in Alabama

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Blueberries are a high value fruit crop that is becoming increasingly popular worldwide. Alabama's blueberry farm gate value has increased by approximately 13% in the last decade. Proper cultivar selection is one of the first and perhaps the most important decisions a grower can make when planting blueberries. The University of Georgia Blueberry Breeding Program has accelerated the development of rabbiteye blueberry varieties in the past two decades in order to facilitate commercial and home garden demand for new varieties. A new large-fruited rabbiteye blueberry cultivar named 'Titan' was released in 2010. Rooted plants from 'Titan', 'Alapaha', 'Brightwell', 'Vernon', and selections '03-06', 'T-611', 'T-743', 'T-957', 'T-965', each represented by 5 plants were introduced to Alabama in 2011 to study the plant development and productivity in our environment. Blueberries were planted at the North Alabama Horticulture Research Center (NAHRC), Cullman, as a RCBD experiment. Our results suggest 'Alapaha' produced the highest cumulative (2013-2017) yield of 19.0 kg/plant, followed by 'Brightwell' and 'Titan' (16.6 and 16.2 kg/plant respectively). 'Titan' and selection 'T-965' had the largest fruit size during the period of study. Berries of 'T-965' matured very early in the season. During the years of establishment cultivars 'Alapaha', 'Titan', 'Brightwell', 'Vernon', and selections 'T-965', were highly productive in Alabama environment.

Keywords: Yield, fruit quality, phenology

P13: Relationships between fruit rot resistance and horticultural traits in America cranberry (*Vaccinium macrocarpon* Ait.)

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American cranberry (*Vaccinium macrocarpon* Ait.) is an economically important crop severely affected by fruit rot, a disease complex including at least 13 fungal pathogen species. A large, advanced, replicated population (219 progeny) with high yielding parentage and three diverse sources of fruit rot resistance (FRR) was evaluated under severe fruit rot pressure for percent rot, yield, berry size, titratable acidity (TA), soluble solids (°Brix), and total anthocyanin (Tacy) content. Progeny were planted in a randomized complete block design (RCBD), with four reps, and data collected over two years. This study considers how breeding for FRR impacts horticultural traits. Significant genetic variation was observed for all traits evaluated; for example, Fruit rot ranged from 8 - 90%, yield ranged 17 – 243 g/0.09 m², and TA ranged 1.6 - 2.6%. Though major loci for organic acids contributing to TA have been identified in other *V. macrocarpon* accessions, the variability exhibited by this population suggest additional quantitative loci influencing acidity. High yielding, low fruit rot individuals were identified, which have potential for commercialization or as FRR parental material. For example, one progeny had a mean yield of 248 g/0.09 m² and 12% rotted fruit (versus a susceptible control with 146 g/0.09 m² and 86% rot). Correlations between FRR versus horticultural and fruit chemistry traits were < |0.15| % suggesting low to no linkage, indicating traits are largely independent. Genotyping-by-sequencing should provide QTL for traits of interest and facilitate breeding for FRR and fruit quality.

Keywords: Fruit rot resistance, *Vaccinium macrocarpon*, plant breeding, fruit quality

Session 2: Germplasm and Propagation

P14: Optimizing lighting conditions in tissue culture for blueberry

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Lighting conditions in tissue culture are essential in determining plant structure, orientation, and overall health. When performing genetic transformation experiments on blueberry, key traits include number of shoots and weight of usable plant material. These traits influence the usability of the plant tissue for use in the CRISPR/Cas9 system. The number of shoots indicate the level of plant growth over a specified period, with higher numbers indicating more growth. Similarly, weight of usable material indicates the weight and growth of shoots and leaves after the removal of calli, which cannot be utilized in the transformation experiments. Here our objective was to develop a protocol to determine optimal lighting conditions to increase the number of shoots per plant, while encouraging the formation of usable plant material and discouraging the production of unusable material. To determine the optimal lighting conditions for genetic transformation of blueberry, we introduced 378 clonal plants of the cultivar Farthing, previously established into tissue culture, into three separate treatments of 126 plants each. The treatments consisted of 77% red/23% blue LED lights, white LED lights, and white fluorescent lights. All treatments were exposed to an intensity of $55 \pm 12 \mu\text{molm}^{-2}\text{s}^{-1}$. After a 100-day period in treatment, the number of shoots was counted, and weight was recorded. Our results showed that treatments presented a significant difference between red/blue and white lighting conditions, with red/blue lighting conditions exhibiting higher number of shoots and higher usable weight. Information obtained in this study will guide the cultivation of blueberry in tissue culture and will contribute to the knowledge on preparing blueberry for genetic transformation. In addition, to our knowledge, this is the first protocol of lighting optimization obtained for blueberry with the goal of genetic transformation.

Keywords: Southern highbush, *Vaccinium spp.*, lighting system, in vitro propagation, LED

P15: First outcomes of grafting highbush blueberry in Romania

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Growing blueberries is of great importance nowadays due to the high content of antioxidants in the fruits and for a healthy diet. Most of the blueberry planting material delivered by nurseries are own-rooted plants and is originated from cuttings or in vitro propagation. Grafting the berries was never considered a reliable alternative for same purpose. Nevertheless, conducting blueberry plants with a single trunk and choosing a robust rootstock for the varieties brings several traits of interest for growers, including the easiness of harvest. Twelve grafting combinations and two grafting methods were tested in potted highbush blueberry plants. 'Blueray' and 'Coville' varieties were used as rootstock and scion as well among the other four varieties like 'Denise blue', 'Bluecrop', 'Pink lemonade' and 'Duke'. Chip budding method proved to be unsuitable for grafting blueberries independent of varieties combinations, but whip & tongue grafting registered 96% success rate. Grafted plants were compared in terms of total annual growth, number of ramifications, number of floral buds per scion and thickness differences in the grafting area.

Keywords: *Vaccinium corymbosum* L., pots, whip & tongue, chip budding, compatibility

P16: In vitro cultivation of *Vaccinium arctostaphylos*, section Hemimyrtilus

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Edible plant species are the most important part of human and animal nutrition. Cultivation of plants, prospective in food production, medicine, nutritional supplement and cosmetic industry, is needed in order to find out and introduce new varieties, new species and products to the market, which will secure wide variety of fresh fruits, spices, herbs and vegetables. Fruits of *Vaccinium arctostaphylos* are used by native people mainly for fresh consumption. *Vaccinium arctostaphylos* grows in several countries including Turkey, Iran, Bulgaria and Russia. Plants can be found in oak, coniferous, beech and hornbeam forests with acid soils. Genotypic expression within the species is very broad. The plant habitus as well as the height of the plant, size of flowers, fruits and leaves are different within and between regions. The aim of the present study was to develop a protocol for *in vitro* propagation of seeds from *Vaccinium arctostaphylos* and to observe the germination rate and the impact of gibberellic acid treatment on germination. Culture media WPM 0 was used for seeds and culture media WPM 0.5 was used for seedlings and shoot propagation. *Vaccinium arctostaphylos* needs to be cultivated in ideal conditions as the germination rate is very low due to possible inbreeding in some locations, which results to the low germination rate.

Keywords: Edible plants, medicine, cosmetics, *in vitro*, propagation, germination rate, gibberellic acid, culture media WPM 0, culture media WPM 0.5, seeds, seedlings, inbreeding

Session 3: Pollination, Production Systems and Sustainability, and Precision Agriculture

P17: Optimizing honey bee hive densities and using pheromones to increase blueberry pollination

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Honey bees (*Apis mellifera* L.) are the primary pollinator in commercial blueberry (*Vaccinium corymbosum* L.) systems in the Pacific Northwest region of the United States. However, floral morphological features and environmental conditions during bloom can limit honey bee activity and ultimately reduce crop yields. The objective of this research was to evaluate in-field practices that have the potential to promote honey bee pollination and subsequent yield components in the pollination-limited conditions of western Washington through two field experiments. The first experiment tested the impacts of modified honey bee hive densities (20 and 25 hives/ha compared to the industry standard of 10 hives/ha) in 'Duke' and 'Draper' blueberry, while the second experiment evaluated the efficacy of synthetic pheromones and attractants in 'Draper' blueberry. Pheromone and attractant treatments included: 1) Bee-Scent, 2) Pollinate Pro, 3) Honey Bee Magnet, 4) SureSet-Apex, 5) distilled water control, and 6) a no-water control. Data for both experiments were collected in 2018 and 2019. Results showed that increasing honey bee hive densities is a promising strategy to improve honey bee activity in pollination-limited conditions, but variables like hive quality and overall management need to be accounted for. Furthermore, commercial pheromones and attractants do not increase honey bee foraging nor other measured yield components. Results indicate that growers seeking to improve pollination should try increasing honey bee hive densities and exclude use of the tested pheromones and attractants.

Keywords: *Vaccinium corymbosum*, *Apis mellifera*, fruit set, pollination efficiency

P18: The wild blueberry industry in North America

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Wild blueberries, principally *Vaccinium angustifolium* with a minor component of *V. myrtilloides* are early successional species that colonized the sandy acidic soil that was produced with the melting of the glaciers 10,000 years ago in North America. As forest succession developed an over story, wild blueberries were able to persist in the understory until disturbance events released them. They provided an important food source for wild animals and for the Native Americans who learned to periodically burn over the forest and for European settlers who cleared the forests for heat and lumber. Management then consisted of periodic burning fields to rejuvenate wild blueberry growth. With the domestication and worldwide spread of the cultivated blueberry (*V. corymbosum*), it became necessary to improve productivity and efficiency to remain competitive in the marketplace. Fields were de-rocked and leveled to allow for mow-pruning and mechanical harvesting, and inputs increased to include, fertilizer, herbicides, fungicides, importing hives for pollination and irrigation. This allowed productivity to increase from 300 to 5,000 kg/ha with highly managed fields able to produce in excess of 10,000 kg/ha. Production of wild blueberries now averages 100 M kg with a high of 400 M kg in 2016. Integrated Pest Management techniques were developed and adopted to increase the effectiveness of and to eliminate unnecessary pesticide applications. Although cultivated lowbush plantings have been established on a limited basis this has proved unsuccessful financially due to the high establishment costs and slow plant establishment. Wild blueberries constitute a unique natural resource of high genetic diversity that exists in Maine, the Maritime Provinces and Quebec, that cannot be duplicated. Wild blueberries are the most successfully managed wild crop in the world without equal.

Keywords: *Vaccinium angustifolium*, managed wild crop

P19: Upright training system for blueberry

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The fresh blueberry market requires manually picked fruits and careful postharvest handling. In support of speeding up the harvest process and improve the fruit quality we design an innovative upright training system for blueberry that focused on modifying the bush architecture. The trial was set up in 2016 using ‘three-years-old plants of Coville’ and ‘Blueray’ varieties planted in pots of 50 litres with peat, sawdust and perlite in equal parts. In the spring, plants were special pruned in order to obtain from bushes, one, two and three vertical axes per plant and container. For the upright conducted blueberry plants, a training system with four wires distanced at 40 cm and individual bamboo sticks to support the stems was provided. During 2016-2019, yield and biometric characteristics were evaluated for all four variants. The experiment reveals a very good behaviour of blueberry in the vertical training system. The height of the cordons stabilizes around 165 cm, and the yield was higher as the number of axes increased. Even though the total production was slightly better in bush comparing to the vertical axes systems, the quality of the fruits in terms of size and colour was greater in the vertical training system. The plants conducted with one axe registered an average yield for the first harvests of 1.00 kg/plant, the ones with two vertical axes of 1.16 kg/plant, and the plants with three axes 1.18 kg/plant. The control bush-shaped blueberry plants yielded an average of 1.21 kg/plant. Beside the fruits appearance, the upright training system for blueberry comes with several other advantages such as compact ripening of the fruits, easy picking and pruning, better light valorisation and land use for small farm units.

Keywords: *Vaccinium corymbosum* L., vertical axes, cordons, trellising, high-density, pots

P20: Pollination compatibility and parthenocarpic berry set in autumn-bloom rabbiteye blueberry cultivars and breeding lines

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Rabbiteye blueberry (*Vaccinium virgatum* Aiton) is a highly self-incompatible species and requires cross pollination to improve berry set and berry size. It has been noticed that several cultivars and breeding lines produce apical bloom in the subtropical autumn climate in Taiwan, offering opportunities for off-season berry production. However, the limited autumn bloom cultivars and insect pollinators might restrict cross pollination and thus reduce yield and berry size. In this study, flowers of four autumn bloom cultivars or breeding lines, 'Myers,' 'Blueshower,' 'NTU-15-070' and 'NTU025', were either open-pollinated or emasculated and then self- or cross-pollinated with each other to test their compatibility. In 'Myers,' berry set was significantly improved by open or cross pollination, but berry size was improved only by cross pollination. In 'Blueshower,' pollination effects varied among pollen donors.

'Blueshower' pollinated with 'Myers' produced the greatest berry set but pollinated with 'NTU-015-070' or 'NTU025' had greatest initial berry growth rate. In 'NTU-15-070' and 'NTU025', no difference in berry set or initial berry growth rate was observed among open-, self-, and cross-pollination, indicating a high degree of self-compatibility.

E emasculated and isolated flowers of 'NTU025' also had a high percent berry set similar to open- or self- pollinated flowers, suggesting a possibility of parthenocarpy in this breeding line. With open pollination, 'NTU-15-070' and 'NTU025' might produce marketable berry size and acceptable yield in autumn of the subtropical climate.

Keywords: *Vaccinium virgatum*, parthenocarpy, off-season bloom, berry set, berry size

P21: Application of small unmanned aerial systems for spatial and temporal assessment of plant water deficits and irrigation needs in northern highbush blueberry

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Washington State is a leading producer of cultivated highbush blueberries (*Vaccinium sp.*) in the United States. However, many growers in this region are facing serious water limitations due to warmer and drier weather conditions, increased regulations, and greater demand by other sectors. The purpose of the present project was to investigate new remote imaging techniques for assessing the need for irrigation in blueberry and better prepare the industry against future water uncertainties. To do so, three years of remote images were collected at least monthly from commercial field sites located throughout the state using a low-altitude, unmanned aerial system (UAS or drone) equipped with a multispectral and a thermal imaging camera. The images were processed and analyzed for normalized difference vegetation index (NDVI) and canopy temperature. While physiologically-based indicators can only be measured in a limited number of plants, remote imagery collected with the UAS was a quick and easy method to provide information on every plant on the farm. Fields were mapped on a block-by-block basis, providing an invaluable tool for water management. The NDVI images provided clear information on development of the canopy in the fields and to estimate the irrigation needs at each site. Thermal images were also useful, particularly for assessing spatial variability in water status of the fields. For example, thermal imaging revealed that large sections of a 4.5-ha field were under-irrigated. Although there was no visual evidence of drought stress in these plants (i.e., no wilting), it turned out that many of the drip emitters located in the under-irrigated sections were plugged. Such information enables growers to quickly identify problems with their irrigation systems. Growers can also use the images to determine whether they are scheduling irrigations properly or need to add more water to the field.

Keywords: Crop coefficients, drought, irrigation, NDVI, remote imaging, *Vaccinium corymbosum*

P22: Evaluation of 'O'Neal' pollen performance on highbush blueberry fruit size and quality

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Open-pollination using pollinator insects is the normal pollination style for commercial highbush blueberry (*Vaccinium corymbosum* L.) production. Pollen source can be one of the important factors to determine fruit set, fruit size and maturation time. Our previous studies on artificial cross-pollination combinations suggested that there is a significant difference in fruit size among 'Chandler' fruits with different pollen genotype sources and 'O'Neal' pollen produced the largest fruit in two years' experiments. This study investigated the effects of artificial pollination with 'O'Neal' pollen on other highbush blueberry cultivars. 'Blue muffin,' 'Sharpblue,' 'Biloxi' and 'Sunshine blue' fruits obtained after artificial pollination with 'O'Neal' pollen contained mature seeds more than the open pollinated fruits did. In addition, the 'O'Neal'-pollinated 'Sharpblue' and 'Biloxi' produced significantly larger fruits than the open-pollinated ones. These results further supported the usefulness of 'O'Neal' pollen to increase fruit size. To clarify the mechanisms underlying the promotional effect of 'O'Neal' pollen to produce fruits with more mature seeds, we examined the pollen viability. Pollen germination tests at 10, 15, and 20°C revealed that 'O'Neal' pollen showed significantly higher germination rate than 'Misty' and 'Sunshine blue' pollen. Based on these results, we hypothesize that higher pollen viability of 'O'Neal' pollen may contribute to produce fruits with larger amount of mature seeds and thus larger fruit. Sugar content, acidity and anthocyanin content of the 'O'Neal'-pollinated fruits did not significantly differ from open-pollinated fruits regardless of increased mature seed numbers. In addition, fruit quality parameters did not show clear correlation with mature seed numbers in the 'O'Neal'-pollinated fruit of most cultivars. Our studies collectively suggested that pollen viability can be considered as one of the important genetic factors for fruit size control but not for fruit quality control in blueberry production.

Keywords: Blueberry, pollination, fruit size, fruit quality, pollen germination

P23: Challenges to blueberry cultivation in protected environment

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Blueberry only grows successfully in soils with high organic matter content and a low pH. Because there are limited natural habitats, production is recommended on raised ridges or in containers. In this way, the properties of the substrate are easily modifiable. Climate changes and the occurrence of invasive pests greatly limit the traditional production method. Therefore, it is imperative that we carefully study the possibilities of growing blueberries in a protected environment (in greenhouses or under a protective net). These forms of cultivation represent a particular challenge in production: it is crucial to monitor lighting and temperature, as adverse levels of one or more parameters trigger a stress response of the plants. Namely, blueberries are extremely sensitive to environmental factors.

The goal of the study is to accurately follow the cultivation of blueberries 'Duke', 'Aurora', and 'Brigitta' grown in containers and on ridges in a suitable substrate either in a greenhouse or under a protective net. We will carefully monitor the environmental parameters such as air temperature, substrate temperature, relative air humidity, the amount of water in the soil, and the flux density of photosynthetically active radiation (PPFD). Moreover, plant growth and development will be assessed, and measurements of stress parameters and physiological response of plants will be taken (fluorescence of chlorophyll on dark-adapted leaves, photosynthesis, transpiration, WUE water use efficiency, stomatal resistance, and leaf temperature). Furthermore, different production methods will be evaluated in terms of fruit quality with measurements of color, mass, firmness, content of primary metabolites such as sugars and organic acids and content of phenolic compounds. Results will be presented for the first three years after planting.

The aim of detailed monitoring of lighting and temperature is to assess the stress in order to prevent it and, consequently, ensure balanced growth and development of plants, regular yields and, above all, consistently high quality of the crop.

Keywords: *Vaccinium corymbosum*, greenhouse, protective net, containers, raised ridges, stress, fruit quality, plant growth

P24: Wild blueberry fields at Downeast, Maine are warming faster than the whole region of Maine

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Wild blueberries (*Vaccinium angustifolium* Aiton), an economically and culturally important native North American fruit crop, are produced intensively at Downeast Maine, USA. The blueberry barrens in Maine are mostly located in coastal regions which might experience different rates of climatic changes compared to the whole state of Maine. Therefore, we analyzed the trends in the maximum (Tmax), minimum (Tmin) and average (Tavg) temperatures, total precipitation (Ptotal), and potential evapotranspiration (PET) for 26 wild blueberry fields in Downeast Maine during May–September over the past 40 years from 1980 to 2019. We also evaluated the effects of these climate variables on the Maximum Enhanced Vegetation Index (EVI_{max}) using Remote Sensing products and Geographic Information System (GIS) tools in Arc GIS Pro software. We observed that the studied 26 wild blueberry fields in Downeast, Maine have been experiencing higher rates of increasing maximum, minimum, and average temperatures than those of the state of Maine during the last 40 years without any increments in rainfall pattern. In fact, the fields closer to the coast are experiencing warmer climates compared to the fields more distant from the coast. As a result, PET or crop water use has been also increasing in the studied wild blueberry fields during 2000-2014 compared to the 1970-2000 period. We also observed significant quadratic relationships of Tmax and PET with EVI_{max} for those fields where an optimum Tmax and PET for EVI_{max} at 22.4 °C and 145 mm/month suggest potential negative effects of warming and increasing PET on crop health and productivity. This alarming information on climate change patterns of wild blueberry fields would help the researchers and growers to employ integrated field management techniques with appropriate resources (e.g., soil amendments, irrigation) on the verge of predicted further warming and droughts.

Keywords: Climate change, temperature, precipitation, potential evapotranspiration, enhanced vegetation index, fruit crop

P25: Improving production efficiency in 'Legacy' blueberry through pruning, training, and harvest techniques

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'Legacy,' a hybrid between northern and southern highbush blueberry, is commonly planted in Oregon, for its very high yield of quality fruit in the mid- to late-season. The vigorous growth habit and relatively long fruiting season make 'Legacy' more costly to prune and harvest by hand. A planting was established in October 2015 to develop more efficient production practices including three pruning or training treatments (started in winter 2017-18): 1) typical pruning for northern highbush cultivars (HB); 2) modified pruning for 'Legacy', leaving more small, thin fruiting wood (Control); and 3) Control pruning plus training to a V-shaped trellis with a goal of more efficient harvest (V).

Time required to prune was not affected by pruning method in 2 of 3 years. In winter 2018-19, pruning of the V plants required more time due to the additional work of tucking canes between the wires (484 hrs/ha) compared to the other treatments (averaged 340 hrs/ha). In the first two years, more pruning wood was removed in the HB and V treatments than the Control, but in 2019-20 treatments did not differ (averaged 1.2 kg/plant). Some extra wood was removed from V plants to better open the center to simplify training, likely accounting for the similar pruning weights to HB pruning. In 2019 and 2020, the first two harvests were by hand and the last two by an over-the-row machine harvester. Yield was not affected by pruning method in the first two years but in 2020, V pruning/training had higher yield than HB (6.0 and 5.1 kg/plant, respectively). During the study period, pruning method has not affected berry weight or total soluble solids (averaging 2.2 g and 14.7% in 2020), harvest efficiency (time/kg of fruit), or percent of fruit dropped during harvest (8% for hand harvest, 18% for machine harvest in 2020).

Keywords: Trellis, machine harvest, labor requirement, fruit quality

P26: First results from a high tunnel experiment with soilless culture of American cranberries under Nordic conditions

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The aim of our research is to enhance current understanding of how the Nordic environmental conditions affect yield, quality, and phenolic contents of the cultivated cranberry (*Vaccinium macrocarpon* Ait.) fruit. So far, the efforts to cultivate cranberry in Finland have been unsuccessful due to winter injury and the inadequate number of GDDs. Worldwide, many berry crops are commonly produced in simple controlled environment structures such as high tunnels (HT). To our knowledge this is the first report on cranberry production in HT. An experiment with seven *V. macrocarpon* cultivars was established in 2015 in southern Finland (60°N, 25°E) to evaluate application of soilless culture in HT to cranberry production.

The effect of HT on the first-year growth, development and overwintering of *V. macrocarpon* plants was evaluated. More biomass was accumulated in HT than under open field conditions; faster growth was explained by the excess of 200 GDDs accumulated in the HT. Due to widely fluctuating temperature, cultivars sensitive to abiotic stress may not be suitable for HT. All plants survived the winter but suffered considerable damage. HT treatment improved the winter hardiness. In the spring 2016, cv. *Pilgrim* was significantly earlier than others, and its yield potential was in a class of its own. In 2016, five cultivars were selected to further study their yield potential in soilless culture in HT, and to be planted out in raised beds in the open field. HT treatment increased yield significantly and consistently over three harvests (2016-2018).

Our preliminary results indicate that *V. macrocarpon* cultivars may benefit from the protected growing conditions and higher accumulation of GDDs in HT, and that cultivars may overwinter successfully in the current climate of southern Finland.

Keywords: American cranberry, *Vaccinium macrocarpon*, high tunnel, Nordic region

P27: Strategies to reduce supra-optimal temperatures during field and containerized production of highbush blueberry in warm climates

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The roots of highbush blueberry are sensitive to high temperatures and tend to grow poorly in warm soils or warm soilless media. Three experiments were conducted to evaluate strategies for reducing temperatures in the root zone in Évora, Portugal, where soil can reach temperatures > 45 °C. The first experiment was conducted in a small planting of 'Ozarkblue' blueberry. Treatments included bare soil, a 10-cm-deep layer of aged pine bark mulch, and black, green, and white geotextile landscape fabric. Bark mulch and green landscape fabric resulted in the lowest mid-day soil temperatures among the treatments, which improved canopy development and survival of the plants during establishment. White geotextile fabric also reduced soil temperature but resulted in a considerable amount of weed growth under the fabric. The second experiment was likewise conducted on 'Ozarkblue', but, in this case, the plants were grown in 40-L pots filled with a soilless mix of three parts peat, two parts pine bark, and one part humus, by volume. Treatments included black pots and black pots covered with white geotextile landscape fabric. After a year, canopy volume of the plants was greater in black pots than in white pots; however, yield was not affected by pot color. The third experiment was conducted in a 2-year-old planting of 'Legacy' blueberry. Treatments included no shade and 60% green shade netting. The netting had no effect on soil temperature in the root zone as a result of the fact that 1) the canopy of plants intercepted the majority of the radiation at midday and 2) frequent irrigation mitigated changes in soil temperature. On the basis of these results, bark mulch and green landscape fabric appear to be the best options for reducing temperatures in the root zone of blueberry in warm climates.

Keywords: *Vaccinium corymbosum*, maximal soil temperature, weed mat, shade net, container color

P28: Ecological niches and leaf economic spectrum across genotypes of *Vaccinium angustifolium* and *Vaccinium myrtilloides* in a semi-natural agricultural system

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Wild blueberries are an important crop to the state of Maine commercially and culturally that are characterized by high inter-genotypic variation both within and across two main species *Vaccinium angustifolium* and *Vaccinium myrtilloides*. These wild blueberries grow by rhizomatous system underneath the soil but above ground appear as a mosaic of individual genotypes where they differ in biological traits, like age, height, color and hue, phenology, and yield. However, we do not know whether the variation within and across these two species follow the principles of leaf economic spectrum (LES) across species and whether they have a different set of resource requirements or share resources for the stable coexistence. For that, we studied different LES trait relationships with respect to global leaf economic trait relationships, compared the role of changing environmental factors in shaping trait relationships over years, and how it could shape the trait relationships. We also tried to understand if LES trait holds true at the local scales in a unique wild blueberry system. The study was conducted in Blueberry Hill Farm Research Station, Jonesboro, Maine in 6 genotypes each of *Vaccinium angustifolium* and *Vaccinium myrtilloides* for the period of 4 years in two crop growth cycles. These wild blueberry genotypes show strong variation both within and across *V. angustifolium* and *V. myrtilloides* species in leaf physiology, nutrient, and structure. The variation among stems was higher compared to genotype variation. *V. angustifolium* and *V. myrtilloides* species did not agree with the global leaf economic spectrum and hold inconsistent relationships but were able to fall within the domain of GLOPNET species. The PCA (Principal Component Analysis) analysis also revealed the influence of changing environmental conditions in shaping different leaf physiology, nutrient, and structural traits and how it plays a vital role in shaping both coexistence and competition behavior of the species. The findings are important to understand the ecophysiology of the wild blueberry system and their response to climate change in terms of species coexistence and distribution.

Keywords: Leaf Economic Spectrum, coexistence, competition, wild blueberry, intergenotype variation

Session 4: Soil Fertility, Plant Physiology and Plant Nutrition

P29: Determining optimal nitrogen fertilizer sources and rates for organic highbush blueberry grown in high pH soils

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Washington is an important producer of organic highbush blueberries (*Vaccinium corymbosum* L.) in North America with half of the production concentrated in an area where native soils are naturally high in pH, free calcium carbonates may be high, and organic matter is low. Despite the economic significance of this region and industry, there is a lack of blueberry nutrient management recommendations specific to this unique production area. The objective of this study was to evaluate different commercially available organic nitrogen (N) fertilizer sources and rates on select plant and soil characteristics using 'Duke' blueberry. Four organic N fertilizer sources applied at three rates were evaluated in a split-plot randomized complete block design experiment with four replications from 2018 to 2019. Main plot fertilizer sources were: 1) blood meal; 2) fish emulsion; 3) WISErganic (made from digested food materials and byproducts); and 4) combination (40% blood meal and 60% WISErganic). The subplot factor was fertilizer rate split within source at 57, 112, and 168 kg·ha⁻¹ N. Differences in yield and whip production were not observed across the fertilizer treatments during the two years in which this study was conducted. Fruit quality variables were marginally impacted by the treatments, but firmness did tend to increase at higher fertilizer rates.

Leaf N concentrations increased with higher rates of fertilizer, but all nutrients were within the recommended sufficiency range except for potassium, magnesium, and copper. Soil pH during the experiment was slightly above the recommended range of 4.5-5.5 and measurements using ion-exchange resin membranes showed a higher concentration of nitrates in soils than anticipated. This work is ongoing and will provide valuable information to guide organic fertilizer N recommendations for blueberry grown outside of native soil conditions.

Keywords: *Vaccinium corymbosum*, blood meal, fish emulsion, certified organic

P30: Relationship between summer-autumn flowering and air temperature in highbush blueberry

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To apply summer-autumn flowering of highbush blueberry to two-season harvesting, we investigated the number of flowering shoots in summer-autumn for 19 'Bluetta' and 19 'Patriot' highbush blueberry bushes at the Takizawa experimental farm of Iwate University, in northern Japan, over five years beginning in 2014. We then discussed the air temperature conditions that induce summer-autumn flowering. Summer-autumn flowerings occurred from late July to early November. The total numbers of flowering shoots in summer-autumn were 37, 24, 115, 115, and 179 in 'Bluetta' and 42, 13, 50, 47, and 88 in 'Patriot' in 2014, 2015, 2016, 2017 and 2018, respectively. The correlations between the total number of flowering shoots in summer-autumn in each year and the average daily mean air temperature, daily maximum air temperature, and daily air minimum temperature every 10 days from June to October were investigated. In both cultivars, there were negative correlations ($r = -0.979 \sim -0.547$) of the mean air temperature, maximum air temperature, and minimum air temperature with the total number of flowering shoots in summer-autumn in mid-June and early August. However, these air temperatures had positive correlations with the total number of flowering shoots in summer-autumn in most of the period from late June to mid-July and from late August to late October in both cultivars. These results suggested that low air temperature may stimulate the induction of summer-autumn flowering in mid-June and early August. After that, high air temperature may promote shoot growth and may increase the number of summer-autumn flowerings in highbush blueberry. Air temperature only partially explained the annual difference in the change of the occurrence of summer-autumn flowering.

Therefore, factors other than air temperature may also affect the occurrence of summer-autumn flowering in highbush blueberry.

Keywords: *Vaccinium corymbosum* L., two-season harvesting, Bluetta, Patriot

P31: Plant growth promotion by heat-resistant fungi isolated from blueberry fruit

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The lowbush blueberry (*Vaccinium angustifolium* and *V. myrtilloides*) grows wild under nutrient and drought-stressed environments in eastern North America. Blueberries are known to coexist with symbiotic fungi, such as ericoid mycorrhizal fungi because they grow in such stressed environments. Recently we have successfully obtained heat-resistant fungi from frozen lowbush blueberry fruits. These fungi included *Leohumicola verrucosa*, which could be ericoid mycorrhizal fungi. Although the ecological nature of these fungi is not clear, it is highly likely that they live in soil and/or plant roots. Therefore, we performed the following experiments in this study. Frozen low-bush blueberry fruits from North America and sterilized water were homogenized, heated at 80 °C for 30 minutes, mixed with potato dextrose agar medium, and cultured at 25 °C for 2 weeks. A total of 256 heat-resistant fungi were isolated from 25 kg blueberry fruits. Five species, *Hamigera striata*, *H. avellanea*, *Devriesia shelburniensis*, *L. verrucosa*, and *Geminibasidium donsium*, were randomly selected from these isolates and used for inoculation tests on seedlings of blueberry, Chinese cabbage, tomato, cucumber, pea and strawberry. Aseptically cultured seedlings were grown on colonies of these fungi on oatmeal agar medium with Nature Aid (Sakata Seed, Yokohama, Japan) as an organic nitrogen source. After 2 to 6 weeks, the dry weight or seedling sizes were measured. All plants grew healthy and all isolates showed a plant growth promoting effect. These fungi may be involved in the growth of plants, including blueberries, in nature.

Keywords: Lowbush blueberry, *Vaccinium angustifolium*, *Vaccinium myrtilloides*, heat-resistant fungi, mycorrhizal fungi

P32: The use of manure-derived ammonium sulfate in blueberries

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Blueberry production in Northwestern Washington State has grown 345% in the last decade and occurs adjacent to dairy operations that are in the top 1% in productivity in the United States. Dairy operators in this region have had to manage an increasing amount of manure as herd size and productivity increase. Manure nutrient recovery technologies create nutrient dense products through a refinement process and are currently operated at commercial scale at a few dairies in this region. These technologies offer the opportunity to transfer nutrients from areas of concentration (dairies) to areas of demand (blueberries) and potentially reduce the need to import nutrients into the region but concerns over food safety arise. A three-year study was performed in a commercial 'Draper' field by substituting total nitrogen (N) from conventional fertilizers with ammonium sulfate derived from dairy manure.

Treatments included conventional fertilizer, manure-derived ammonium sulfate, and manure-derived ammonium sulfate split into two applications. Plant growth, foliar nutrient content, yield quantity/quality, and soil nutrient levels were monitored. Soil, fertilizer, foliar, and fruit samples were collected during the cropping season for the quantification of indicator microorganisms and detection of important foodborne pathogens including Shiga toxin-producing *E. coli* (STEC), *Salmonella*, and *Listeria monocytogenes* using traditional culture methods. No significant differences were observed in plant growth, yield, or foliar N content between the treatments. The population of total coliforms in soils were 3.2-3.8 Log₁₀ CFU/g, which were stable throughout the production season regardless of fertilizer treatments. *Salmonella*, STEC and *L. monocytogenes* were below the detection limit in fertilizer, soil, foliar and blueberry fruit samples collected during production seasons. The trial concluded that there was little food safety risk when using manure-derived ammonium sulfate and that it is possible to utilize this nutrient source to maintain crop productivity.

Keywords: *Vaccinium corymbosum*, nutrient management, ammonium sulfate, food safety

P33: The relationship between moisture content of soilless media and floral nectar in potted Southern highbush blueberry

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Australian blueberry crops can be poorly pollinated, possibly associated with the use of hail netting or other crop covers that may limit pollinator movement. Nonetheless, the floral nectar of blueberry crops is a key attractant for honey bees, marked by its high sugar content. Also, higher rates of visiting insects to blueberry flowers have been observed when nectar is abundant. A potential approach to attracting pollinators to blueberry crops may be to optimise floral attributes, including maximising nectar production. Nectar production in blueberry flowers can be affected by variety, and environmental conditions such as solar radiation, temperature and humidity. The aim of this study is to observe the relationship between moisture content of the growing medium and the production and quality (%Brix) of floral nectar of southern highbush blueberry. There is potential for optimising nectar production through irrigation management, particularly in a potted soilless system. Preliminary results on the relationship between moisture content of a coir and peat based medium and floral nectar production and quality will be presented.

Keywords: Substrate, hydroponics, *Vaccinium corymbosum*, soluble solids

P34: Comparison of methods for applying boron fertilizers in northern highbush blueberry

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Previous studies indicated that fertigating with N was more effective than using granular N fertilizers in northern highbush blueberry (*Vaccinium corymbosum* L.). The objective of the present study was to build on these findings and determine whether fertigation was also an effective method for applying B. Treatments were applied for 2 years to two cultivars (Earliblue and Aurora) and included no B, granular or foliar application (April) of sodium borate or boric acid, respectively, and weekly fertigation (April-July) with boric acid. Each fertilizer was applied at a rate of 1.8 kg·ha⁻¹ B per year. Each treatment was also fertigated with N and P. Although leaf B was initially deficient in both cultivars, none of the treatments had any effect on yield or berry weight. Leaf B, on the other hand, was significantly affected by the fertilizers. In year 1, B was accidentally applied at five times the intended rate to the foliar treatments and, as a result, leaf B was above the recommended range (30-80 ppm) in 'Earliblue' and sufficient in 'Aurora'. Leaf B was also sufficient with fertigation in both cultivars but low and no different than the controls in the granular treatments. By the following year, leaf B remained low in treatments with no B but sufficient or above range when B was applied by any method in 'Earliblue,' including granular application of sodium borate. However, leaf B remained deficient with no B or granular B in 'Aurora' and was only slightly sufficient when B was applied by fertigation or as a foliar fertilizer. Interestingly, each method resulted in higher concentrations of B and soluble solids in the fruit than no B in 'Earliblue.' At this point, applying B by fertigation or as a foliar is recommended over the use of granular B fertilizers in northern highbush blueberry.

Keywords: Fertigation, foliar fertilizer, micronutrients, plant nutrition, *Vaccinium corymbosum*

P35: Winter hardiness of highbush blueberry cultivar Arto as affected by high tunnel cultivation

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Inadequate winter hardiness limits the production of highbush blueberry (*Vaccinium corymbosum* L.) in Finland. As high tunnel cultivation has been observed to improve winter hardiness in various berry crops, we wanted to evaluate the effect of high tunnel on winter hardiness of the blueberry cv. Arto. The plants were grown either covered by a high tunnel during a growing season, or in the open field. Frost hardiness was measured five times from November 2015 to March 2016 using controlled freezing tests followed by visual rating of injury (buds) and electrolyte leakage measurement (shoots). The depth of dormancy was determined by forcing the shoot samples in a greenhouse, and the concentrations of soluble carbohydrates in the shoots were measured. High tunnel improved slightly frost hardiness of highbush blueberry. High tunnel also delayed both beginning and breaking of endodormancy and changed the pattern of carbohydrate accumulation in blueberry shoot tissues during winter. Our results demonstrated that winter hardiness of blueberry can be improved by high tunnel cultivation. As the tunnel plastic was removed before winter, the differences between the treatments were due to different growing conditions during the growing season. Hence, the growth-promoting conditions in a high tunnel during the growing season improved the ability of the plants to survive in winter conditions.

Keywords: Blueberry, carbohydrates, dormancy, winter hardiness

P36: Effect of temperature on growth and quality of clones of *Vaccinium myrtillus*

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Bilberry (*Vaccinium myrtillus*) is a popular wild growing spice widely distributed over a range of latitudes across Europe and northern Asia. The area in which it is distributed has large differences in climate. When spreading through geographical areas, the species adopt to abiotic and biotic growth conditions. The differences in abiotic growth conditions affect various aspects of plant growth, development, and berry quality. Climate change is predicted to cause quick increases in temperatures, which can be a challenge for many plant species. In order to investigate the plasticity of the plant material to adopt to temperature plants collected from a range of latitudes in northern Europe: from 70 °N-54 °N in 5 countries were grown under controlled conditions at high (20 °C) and low (12 °C) temperatures. Various aspects of growth and flowering as well as berry quality were investigated. Here we present preliminary results from this study.

Keywords: Bilberry, temperature, growth, latitude, climate, growth, quality

P37: Revised leaf tissue nutrient sufficiency standards for northern highbush blueberry in Oregon

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Leaf tissue sampling to determine nutrient concentration is a common practice. Lab results are compared to published sufficiency levels to help inform nutrient management programs. Published tissue nutrient standards were developed from research experiments and estimates from large databases that relate tissue nutrient levels to high yielding fields. Current leaf sufficiency levels are similar for nutrient management guides published in various regions for northern highbush blueberry. Standards are based on nutrient concentrations in recent, fully expanded leaves on lateral shoots located below the fruiting zone. Since leaf nutrient levels vary over the growing season, recommended sampling time is when most or all nutrients are relatively stable to allow for comparison among years. Commonly grown cultivars with fruiting seasons ranging from late-June to mid-September including 'Duke,' 'Bluecrop,' 'Draper,' 'Liberty,' 'Legacy,' and 'Aurora' were evaluated in conventional and organic production systems. Cultivars differed in leaf nutrient levels, but all were best sampled from late July to early August despite differences in fruiting season. While yield was typical in research studies done from 2013–2020, levels of some tissue nutrients were outside of currently published sufficiency standards for the region, particularly for leaf P, K, Ca, and Cu. Leaf tissue sufficiency standards have thus been revised to 1) account for broader variation among cultivars that may result from differences in fruiting season and nutrient allocation, 2) narrow or lower sufficiency standards where research has shown a negative correlation with yield at the higher levels within current sufficiency standards, and 3) add a tissue standard for Al; while Al is not an essential nutrient in northern highbush blueberry, leaf Al concentrations may be used along with leaf Mn to monitor changes in soil pH over time. Revised leaf sufficiency standards for macro- and micronutrients will be presented.

Keywords: Fertilization, tissue sampling, cultivar, organic, nutrient management

P38: Use of symbiotic microorganisms to improve growth, productivity and quality of cranberries grown in Quebec

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Cranberry products are a multi-billion-dollar business worldwide. Canada's share of the global conventional production is around 25%, and 90% of organically grown fruits. However, cranberry farming is faced with complex challenges including diseases and climate stress. In order to improve crop resilience and plant productivity, a large number of mycorrhizal fungi and endophytic bacteria were isolated into cranberry plants (Lang's laboratory). Two of them, the bacterial strain EB37 (*Bacillus velezensis*) and the fungi EC5 (*Lachnum sp.*), revealed promising growth stimulating effect, with large gene sets linked to biocontrol and biofertilization (Lang's lab). To validate the agronomic potential of EB37 and EC5 on cranberries, plant growth, yield and berry quality were evaluated in 2019 at three cranberry commercial farms in Quebec. In 2018, four treatments (1-EB37, 2-EC5, 3-combination of EB37 and EC5 and 4-control) were compared within a complete block design with three replicates by foliar spray applications. Growth parameters (vegetative and fruiting branches, number of branches with aborted fruit) and berries were collected at the end of September. Berries were classified as marketable and unmarketable (misshaped, molded or damaged) fruits, and also divided in red and uncolored (less than 50% of the fruit was red) berries. Regardless of the experimental sites, results showed that EC5 and EB37+EC5 treatments increased the number of fruiting branches by 20% and 30%, respectively, while no significant effect was observed for vegetative branches compared with control plants. The three treatments increased the marketable fruit weight (by 26% and 14% depending on site) and the weight of red berries by 14% on average over all sites. Overall, the total fruit weight increased significantly by 15% for EC5 and EB37+EC5 treatments. No significant effect of treatment was observed for unmarketable and uncolored fruits, nor fruit size. Overall, the percentage of branches with aborted fruit decreased or was similar. Results will also be discussed in terms of postharvest benefits of treated berries.

Keywords: Mycorrhizal fungi, endophytic bacteria, yield, vegetative and fruiting branches

P39: Impacts of warming on wild blueberry physiology and pest pressure

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One of the largest threats to wild blueberry production, with little information on its consequences, is climate change. Atmospheric temperatures have increased significantly in the past century, and the increases are predicted to accelerate in the future. To investigate the effects of warming on wild blueberry physiology and pest pressure, we constructed passive and active heating open-top chambers to manipulate warming for five *Vaccinium angustifolium* genotypes at the Blueberry Hill Research Farm, Jonesboro, ME, USA. Experimental warming (3 to 5°C) significantly increased leaf stomatal conductance, transpiration and water loss, which consequently resulted in lower leaf water potentials and soil water availability compared to the ambient control. Warming had no effects on leaf photosynthetic CO₂ assimilation but decreased the photosynthetic electron transport rates compared to the control. Warming did not cause changes in pest pressure (weed, pathogen, and insect), which could be because of the blocking effects of the chamber walls. Our results suggest that the wild blueberry system will need more water supply (irrigation) to maintain good water status and productivity in the future with a warmer climate. Decreased soil availability will also decrease soil nutrient availability, suggesting that more fertilizer applications will be needed in a warmer future.

Keywords: Climate change, *Vaccinium angustifolium*, water deficits, soil water availability, photosynthesis

Session 5: Pest Management

P40: Potential effects of insects on survival of *Monilinia vaccinii-corymbosi* pseudosclerotia

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Monilinia vaccinii-corymbosi (MVC) is a common fungal pathogen of lowbush blueberry (*Vaccinium angustifolium*) in Maine. The fungus overwinters for one to multiple years as pseudosclerotia in the duff or litter layer in the field. In prior field experiments, the number of pseudosclerotia placed in a field in the fall decreased by the spring. The possible effects of other organisms, such as invertebrates and insects, on pseudosclerotia prior to and during the overwintering process were examined. In 2015 and 2016, field experiments investigating possible animal interactions with pseudosclerotia were set up to compare the loss of pseudosclerotia from treatments with no cages to the losses inside cages with varying sizes of mesh (ranging from 1, 4, 7 and 14 mm). In both years, there were greater numbers of pseudosclerotia remaining inside cages with the smallest mesh compared to larger mesh cages or treatments with no cages and having a cage bottom had no effect on survival. In 2016, there were the same proportion of loss of MVC pseudosclerotia in similar sized cages at the edge and middle of the field. There was little effect of density of pseudosclerotia on proportion of loss. The most common insects collected from pitfall traps in blueberry fields in September 2015 and 2016 were in the families, Gryllidae, Alydidae, Formicidae, Carabidae and Scarabidae. No-choice laboratory experiments using MVC pseudosclerotia and insect members of the most commonly collected families found most of the insects damaged pseudosclerotia, and some broke pseudosclerotia into small fragments. The destruction of the pseudosclerotia may be due to their consumption or to the insects scavenging for blueberry tissue and seeds. Insects present in lowbush blueberry fields may be affecting the overwintering of pseudosclerotia and result in a decrease in potential inoculum in subsequent years.

Keywords: *Monilinia*, lowbush blueberry, mummy berry, pseudosclerotia, insect, survival

P41: Effect of thermal pruning on wild lowbush blueberry (*Vaccinium angustifolium* Ait.) and its environment

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Wild blueberry pruning is a practice that dates back to the Native Americans, who discovered that burning wild blueberry patches increased their yield. Nowadays, pruning is mostly mechanical as it is a cheaper method. However, thermal pruning has the advantage of controlling fungal diseases such as sclerotinia rot, as well as some species of weeds. This can be of great interest in the cases of organic practices which have limited options in terms of pest control. Our study aimed to measure the impact of three burning intensities on the soil chemistry, wild blueberry diseases as well as weeds. We also wanted to know if thermal pruning alters the fungal and bacterial communities of the wild blueberry root and rhizosphere. A randomized block design with four replicates (plots of 6 m x 2.5 m) per block was established at the Bleuetière d'enseignement et de recherche (BER) in Normandin, Quebec. On the 18th of May 2018, following a mechanical pruning, three burning intensities were tested, the remaining one being a negative control. Soil cores were collected before burning, 1 month, 4 months and a year after burning for chemical analysis. Blueberry biomass and blueberry yields were measured during both sprout and cropping years, as well as weed coverage and disease presence. Blueberry roots and rhizosphere were collected during the harvest day (2019) for DNA extraction. Our results on soil analyses show a significant increase of phosphorus content in the organic soil layer 1 month after the burn for the second and third intensities compared to the control. Furthermore, the total weed coverage tends to decrease as burning intensity increases. Blueberry coverage and biomass are not significantly impacted by burning. Our next step will be to compare the bacterial and fungal communities of both roots and rhizosphere from the different burning intensities.

Keywords: Wild blueberry, thermal pruning, weed control

P42: Potential use of biofungicides for the control of Botrytis blossom blight and Septoria leaf spot in wild blueberry fields

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Botrytis blight and Septoria leaf spot are important diseases of wild blueberry which cause significant yield losses annually. Conventional fungicide management of these diseases are faced with the challenge of resistance development in pathogen and public health concerns, hence alternative measures for disease management are important. In this study, the efficacy of Timorex Gold® (Tea Tree Oil), Diplomat 5SC® (Polyoxin D Zinc Salt), Fracture® (BLAD polypeptide) and Serenade Max® (Bacillus subtilis) against Botrytis blight and Septoria leaf spot were evaluated alone and in combination with Switch® under field condition. Three applications of each biofungicide were made for stand-alone treatment, and each rotated with Switch® as combined treatment at 7–10-day intervals.

Diplomat 5SC® and the combination of Fracture® and Switch® significantly suppressed Botrytis incidence and severity by more than 63%. Similarly, Timorex Gold®, Fracture® and Serenade Max® reduced Septoria leaf spot by over 77% compared to the untreated control. Diplomat®, Fracture and Serenade Max® with their combination with Switch® produced greater yields (> 25%) compared to the untreated control. This preliminary study demonstrates the potential efficacy of some biofungicides in managing Botrytis blight and Septoria leaf spots which can help reduce the complete reliance on conventional fungicides.

Keywords: Wild blueberry, *Botrytis cinerea*, Septoria leaf spots, biofungicides

P43: Effect of different fungicides on the control of *Lasiodiplodia theobromae* causal agent of dieback in blueberries in the Chavimochic irrigation project in Peru

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Blueberry is one of the main export fruit crop in Peru, with an area of 13000 ha, of which 6500 ha are in the Chavimochic Irrigation Project in northern Peru. The main disease problem is the dieback caused by the fungi *Lasiodiplodia theobromae*. This pathogen occurs mainly after pruning during the months of December to January where the incidence can be higher than 10 % in several fields. The objective of this research was to evaluate different fungicides for the control of this fungi, both *in vitro* and in inoculated plants in field conditions. Twelve fungicides were evaluated *in vitro* on Papa Dextroxa Agar (PDA) medium, of which five were selected for field evaluation. Under field conditions, the Ventura cultivar was used, where the percentage of diseased stems previously treated with fungicides was evaluated after 65 days. The fungicide with the best performance was Cyprodinil + Fludioxonil, followed by Thiabendazole, which showed statistical differences with the inoculated control. The second field trial was the application of the fungicide Hymexazol applied by drench to the root system, no statistical differences were found between the doses of 2 L/ha and 4 L/ha but a statistical difference was found with the inoculated control. In both alternatives, the aerial application of Cyprodinil + Fludioxonil and soil application of Hymexazol, the control of *Lasiodiplodia theobromae* is effective under Chavimochic Project conditions.

Keywords: *Lasiodiplodia theobromae*, fungicides, blueberries

P44: Parasitoids associated with the invasive pest *Drosophila suzukii* (Diptera: Drosophilidae) in Argentina and their potential role as biological control agents in blueberry orchards

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Argentina's organic blueberry exports totalize approximately 2,200,000 kg, which are mainly shipped to North America, Europe, and SE Asia, mostly from September to November (spring). Organic fresh blueberries range third in volume of organic fruit exported, behind pears and apples. The SWD is an exotic pest that increasingly threatens Argentina's blueberry industry since its irruption in 2014. In northern Argentina, where most of the blueberry acreage is established, the rainy season begins between the end of October and the first weeks of November, bringing on ideal conditions (mild temperatures and adequate soil and air moisture) for SWD reproduction and fruit infestation. For the control of SWD, insecticides are not effective and cultural control is complex. Besides, little is known about local beneficial organisms that could regulate SWD populations. Frugivorous drosophilids are mainly attacked by larvae and pupae parasitoids. The former are endoparasitoids that interact with the host's immune system and tend to have a narrow host range; on the contrary, pupae parasitoids are ecto or endoparasitoids and tend to be generalists, attacking a wide range of hosts. SWD invasion encouraged studies aimed to explore the presence of local parasitoids that would contribute to an environmentally sound management of the pest. Up to now, as result of these studies, several hymenopteran parasitoid species have been identified in blueberry and other berry crops: *Pachycrepoideus vindemmiae* (pupae parasitoid; Pteromalidae), *Trichopria* sp. (pupae parasitoid; Diapriidae), *Dieucoila octoflagella*, *Ganaspis hookeri*, *Ganaspis* sp., *Hexacola* sp., *Leptopilina boulardi*, and *Leptopilina clavipes* (larvae parasitoids; Figitidae). They were captured in traps installed in berry orchards infested with SWD, or among fallen fruit, and/or emerged from fruit infested with SWD. *Dieucoila octoflagella* is a new species, recently recorded in Argentina by our group, whose adult was recovered from SWD pupae. The collection and identification of specimens remain in progress.

Keywords: Ecosystem services, *Vaccinium corymbosum*, natural enemies, sustainable pest control

P45: Soil microbiome of lowbush blueberries under fungicidal management

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Of the diseases which reduce yield in wild blueberries (*Vaccinium angustifolium* and *V. myrtilloides*), fungal pathogens are the most pervasive and apply the highest disease pressures. To protect the plant from fungal pathogens, fungicides are routinely applied starting in the vegetative year of the crop cycle. While the yield-improving effects of fungicides are well-known, their effects on the plant-associated microbiome remain poorly understood. Thus, the goal of this study is to use molecular genomic techniques to examine the effects of the active ingredients chlorothalonil and prothioconazole on the diversity and abundance of soil organisms associated with lowbush blueberry crops in order to assess the impacts of these treatments on agriculturally relevant microorganisms. Soil samples were taken from treatments consisting of the untreated control, applications of the fungicide Bravo® Zn (a.i. chlorothalonil) and applications of the fungicide Proline® 480SC (a.i., prothioconazole).

From this soil, DNA was extracted and analysed using fungal-specific ITS2 amplicon sequencing. The sequenced reads extracted from these samples were cross-referenced with microbial genomic databases using the Qiime2 software to place them in Amplicon Sequence Variants (ASV) – high-resolution taxonomic groupings. Using this data, the impact of broad-spectrum fungicides on the soil fungal microbiome was assessed and the potential effects of fungicide use on long-term soil health was evaluated. By illuminating the relationship between pesticide applications and soil microbiome responses, the results obtained from this research will contribute to the development of ecologically sound agricultural techniques. Furthermore, this work represents the application of new molecular microbiome techniques in the realm of agricultural research, helping to hone techniques whose application may extend beyond the blueberry field into other realms of agricultural science.

Keywords: Lowbush blueberries, genomics, microbiome, fungicides, Monilinia, Botrytis, 16s rRNA

P46: Organic management of weeds in blueberry production in a volcanic soil of Chile

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Weeds are one of the higher problems in blueberry (*Vaccinium corymbosum* L.) organic production in Chile. Use of mechanical control with mowers and manual are de most commons system among producers; however these practices increases weed problems. To determine the effect on annual weeds, an experiment with natural products was performed at Experimental Station of Universidad de Concepcion at Chillan, Chile. Two dose of a mixture of vegetable oils and carbohydrates sprayed on soil (Tradenname: Fitosoil) were evaluated alone or followed by a soil conditioner made from plant extracts that provide phytochemical compounds sprayed over plants (Tradenname: Q-tral active). Both products accelerate the decomposition of organic matter. The soil was an Andisoil with 7.8% OM, loam soil. The sprayed treatments were Fitosoil 300 and 450 cc/m² followed or not by Q.tral active 300 cc/m² once or twice every 30 days. These treatments were compared with weedy check and a hand-weeded every 30 days. Results at 95 days after first spraying showed that treatments including Fitosoil 300 cc/m² and 450 cc/m² followed by 2 applications of Q-tral active were not different than hand-weeded every 30 days and all them reduced significantly weed dry matter compared with weedy check. Similar results were obtained in a Phytroton. The treatments similar than weedy-check were both with Fitosoil alone.

Keywords: Weed control, natural products.

P47: Incidence of spotted wing drosophila infestation in blueberries in Alabama

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Alabama is 12th in the nation in the production of blueberries and consumer demand for the crop is increasing due to the flavor and increased public awareness of the health components found in blueberries. Spotted Wing Drosophila, (SWD) an invasive insect first reported in California in 2008, has hampered blueberry production in the southeast. Spotted wing drosophila was first spotted in Coosa, Chilton counties in Alabama in 2011 and was later found in Elmore County. Spotted wing drosophila can now be found in all 67 counties in the state. Infested fruit are commonly not detected until the consumer has purchased the berries resulting in reduced consumer confidence and purchases. Controlling the spread of SWD is paramount and Sustainable management of SWD will depend on the phenology of the insect. Currently there is little information available about the populations of SWD in the state. Monitoring of SWD will provide information on timing of first flight and peak populations for targeted rather than calendar based spraying of insecticides. Monitoring of SWD occurred at a popular agritourism destination in Central, AL, which featured rabbiteye blueberries in 2018 and 2019 with some limited monitoring occurring previously in 2016 and 2017. Five Captiva SWD traps (Marginal Design, Oakland, CA) were deployed approximately 24 m apart in a two blueberry plantings separated by an access path. The plantings were 0.18 and 0.08 hectares, respectively. A sugar and yeast bait solution was used to attract SWD. Traps were checked and bait solution was refreshed weekly from 23 May to 23 Oct in 2018 and from 30 May to 14 Nov in 2019. Insects from each of the five SWD traps were separated by species and all non-fruit fly species were discarded. Fruit flies were separated into SWD and non-SWD using a dissecting microscope and male and female SWD were counted. In 2018, total SWD population peaked at approximately in July and declined in Sept. In 2019, SWD captures were bimodal, peaking in August and again in October. In both seasons, female SWD occurred in greater number than males reaching ratios as high as 13 to 1 in 2019. More monitoring of SWD is needed to provide blueberry growers with more sustainable means to protect their crops from infestation to preserve the growing blueberry industry in Alabama.

Keywords: Blueberry, Spotted Wing Drosophila, monitoring

P48: Weed survey of Nova Scotia wild blueberry (*Vaccinium angustifolium* Ait) fields

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Weed surveys provide the basis for weed management research in wild blueberry, but have not been conducted in this crop since 2001. Since then there have been documented declines in herbicide efficacy, loss and/or acquisition of herbicide active ingredients, confirmation of herbicide-resistant biotypes of important weed species, and documented vectoring of weed seeds by machinery. A weed survey was therefore initiated in 2017 to assess potential changes in the weed flora of wild blueberry fields in Nova Scotia. A total of 165 bearing year (fruiting) wild blueberry fields were surveyed from 2017 to 2019, within which approximately 211 weed species were identified. Most weed species were herbaceous perennial forbs (89 species) and woody perennials (50 species), followed by annual broadleaf (24 species) and perennial grass weeds (20 species). The remaining flora consisted of a range of ferns, biennials, sedges and rushes, and orchids. The most common weed species were red sorrel (*Rumex acetosella* L.), poverty oatgrass (*Danthonia spicata* L.), haircap moss (*Polytrichum commune* Hedw.), hair fescue (*Festuca filiformis* Pourr.), narrow-leaved goldenrod (*Euthamia graminifolia* (L) Nutt.), tickle grass (*Agrostis hyemalis* (Walter) BSP.), woolly panicum (*Dichanthelium acuminatum* Ell.), cow wheat (*Melampyrum lineare* Desr.), bunchberry (*Cornus canadensis* L.), and yellow hawkweed (*Hieracium caespitosum* Dumort). When compared to previous weed surveys, increased occurrence of these weed species is likely the result of documented or observed reductions in hexazinone and terbacil efficacy, confirmation of triazine-resistant biotypes, and common occurrence of seeds of these weed species on machinery. Low crop prices have also caused reduced pronamide use, contributing to increased occurrence of hair fescue. Results are guiding future research priorities for weed management in wild blueberry.

Keywords: Wild blueberry, lowbush blueberry, weed management, weed survey

Session 6: Berry Composition and Postharvest Attributes

P49: Composition, biosynthesis and effect of environmental factors on the cuticular wax of bilberry fruit (*Vaccinium myrtillus*)

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The outer surface of plants is covered by cuticular wax, which plays a role in non-stomatal water loss, protection from UV rays and plant defense. We have found differences in chemical composition and morphology while characterizing the cuticular wax in bilberry (*Vaccinium myrtillus*), lingonberry (*Vaccinium vitis-idaea*), bog bilberry (*Vaccinium uliginosum*) and crowberry (*Empetrum nigrum*) fruits using GC-MS and SEM analysis. Triterpenoids were found to be dominant compounds in bilberry and lingonberry cuticular wax while fatty acids and alkanes dominated in bog bilberry and crowberry, respectively. All studied berry waxes showed high *in vitro* Sun protection factors (SPFs) depicting high UV-B absorbing capacities.

Developmental and environmental factors are known to play an important role in cuticular wax biosynthesis. Therefore, we have characterized cuticular wax of glossy mutants of bilberry along with wildtype bilberry through developmental stages. The wax load between the mutant and wildtype bilberry was found to be almost similar, however the proportion of triterpenoids was higher; fatty acids and ketones, lower in mutant wax as compared to wildtype bilberry. Based on morphology and compositional analysis, we propose a correlation of glaucousness and rod like structures with ketones and fatty acids in bilberry. Peel specific expression of CER26-like, FAR2, CER3-like, LTP, MIXTA, and BAS genes indicates their role in wax biosynthesis in bilberry. In studying the effect of environmental factors, we observed that the proportion of triterpenoids increases in bilberry cuticular wax as we move from northern latitudes to southern. Phytotron study revealed the effect of temperature on the chemical composition of bilberry cuticular wax, especially triterpenoids.

Our studies bring new information on the biosynthesis and effect of environmental factors on composition, morphology of cuticular wax layer in bilberry.

Keywords: Bilberry, lingonberry, latitudinal gradient, triterpenoids, glossy mutants

P50: Evaluation of extraction methods for determination of phenolic compounds, organic acids and sugars in lingonberries (*Vaccinium vitis-idaea*)

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Health benefits of lingonberries have been linked to phenolic compounds, whereas organic acids and sugars are important for the taste of the berries. Composition of these compounds combined can be used to determine lingonberry quality. Extraction is a critical step in analyses of these compounds, and many different methods have been used. The aim of the study was to test different extraction methods, and to evaluate if one single method could be used to determine quality of lingonberries. Extraction of fresh or freeze-dried lingonberries were performed using water, methanol (at 20 or 60 °C) or acetone as solvent. Berries from two seasons were extracted in triplicate and phenolic compounds and organic acids and sugars were analysed by HPLC-DAD-MS and HPLC-DAD-RI, respectively. Similar results were obtained from fresh or freeze-dried berries, but deviation between parallels was lower when extracting from freeze-dried berries. Methanol was the best extraction solvent for anthocyanins, whereas acetone was more efficient for flavan-3-ols. For extraction of hydroxycinnamic acid derivatives (HCA), flavon-3-ols, organic acids and sugars, methanol and acetone were equally efficient. Depending on extraction method, the concentrations of anthocyanins, flavon-3-ols, HCA and flavan-3-ols in the lingonberries were 56-90, 20- 30, 16-23 and 90-130 mg/100 g, respectively. The organic acids (2.3-3.0 g/100 g) were mainly citric and quinic acid and the sugars (7.5-9.0 g/100 g) were glucose and fructose. The concentrations of phenolic compounds, organic acids and sugars using methanol and acetone as extraction solvents were comparable to those previously reported. Considering both accuracy and time of preparation, extracting freeze-dried berries with methanol was considered the best extraction method for analysing compounds important for quality of lingonberries.

Keywords: Lingonberries, *Vaccinium vitis-idaea*, phenolic compounds, organic acids, sugars, analysis, extraction, methods

P51: Pulp temperature at impact affects southern highbush blueberry fruit quality

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Fresh market blueberry (*Vaccinium spp.*) fruit sustain numerous impacts during harvest, packing and shipping. Blueberry pulp temperature can vary greatly during the handling process due to environmental conditions and commercial handling practices. Tests were conducted with southern highbush blueberry releases from the University of Florida Blueberry Breeding Program ('Meadowlark', 'Colossus' and 'Sentinel') to determine the effect of physical impact at various pulp temperatures on resultant fruit quality. Blueberries were harvested in April 2021 and conditioned at 5, 10, 15, or 20 °C. After 5 hr (simulating same-day packing) or after 24 hr (simulating next-day packing), fruit were dropped once onto a hard surface from 60 cm or were left undropped (control). Fruit were evaluated immediately and again after four days at 5 °C ('Meadowlark') or after one day at 22 °C ('Colossus' and 'Sentinel'). 'Colossus' had the highest initial firmness at 262 g/mm (gram-force/mm) followed by 'Meadowlark' (242 g/mm) and 'Sentinel' (198 g/mm).

Blueberry firmness was affected by impact and conditioning time but not pulp temperature. Dropped fruit were softer than undropped at all evaluation times. Firmness ranged from 180 to 229 g/mm for dropped and from 206 to 263 g/mm for undropped blueberries depending on the cultivar. After conditioning at the various temperatures firmness of dropped fruit after 5 and 24 hr decreased 8% and 6% for 'Meadowlark', 13% and 17% for 'Colossus', and 9% and 7% for 'Sentinel', respectively. Weight loss was unaffected by impact or pulp temperature. However, blueberries conditioned for 24 hr had higher weight loss than those conditioned for 5 hr. Average weight loss after 5 and 24 hr was, respectively, 0.18% and 0.39% for 'Meadowlark', 0.21% and 0.40% for 'Colossus', and 0.22% and 0.39% for 'Sentinel'. Effects on fruit composition and internal bruise severity are currently being analyzed and will be reported.

Keywords: Firmness, bruising, *Vaccinium*, internal damage, injury

P52: Performance of a soft sorter for removing overripe and damaged wild blueberries during processing

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Wild blueberries (*Vaccinium angustifolium* Ait.) are an important horticultural crop in Quebec and the Atlantic Provinces of Canada, producing 132 million kg of fruit, and contributing \$600 million annually to provincial and federal economies. The large majority of harvested wild blueberries are processed and sold as a frozen fruit product. Wild blueberry growers are actively looking toward expanding the existing higher-value fresh fruit market to increase profit margins. Conventional equipment used for fresh wild blueberry processing is labour intensive and requires round the clock personnel to operate seasonally during a short harvesting season. Automated sorting technologies have been developed for the fresh processing of several fruits and vegetables, but little research has been done to evaluate mechanized sorters for wild blueberries. The objective of this project was to compare the ability of an automated soft sorter to remove overripe and damaged wild blueberries as compared to a traditional manually operated processing line. The principal goal of this project is to grow the supply of quality fresh fruit to increase the value of wild blueberries while minimizing processing labor and costs. A scientific comparative analysis of the two fresh fruit processing methods was conducted to aid wild blueberry farmers, processors and stakeholders in making informed decisions when pursuing options for processing wild blueberries for fresh market. Results from this study suggest the automated soft sorter was able to reduce pick over line labor requirements during processing. The soft sorter removed an average of 23.63% of the soft or damaged wild blueberries while mistargeting 0.37% good berries. Further evaluation is suggested using different combinations or additional auto sorters in parallel to determine if increased labor savings can be achieved. It would be valuable to understand any potential benefits from effectively pre-cooling berries prior to sorting in conjunction with monitoring the moisture content.

Keywords: Mechanization, automation, economics, labor savings, agriculture

P53: Aminoethoxyvinylglycine (AVG) does not improve fruit firmness of 'Stevens' and 'Howes' cranberry

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Fruit firmness is an important quality parameter in cranberry (*Vaccinium macrocarpon*) production. Firmer fruit are easier to slice during processing resulting in a more efficient conversion of cranberries to high-value products.

Currently, there are no preharvest cultural practices to improve fruit firmness in cranberry production. The plant growth regulator Aminoethoxyvinylglycine (AVG), has been previously reported to improve fruit firmness in sweet cherry. Sweet cherry and cranberry are both classified as non-climacteric fruit so the mechanism of improving fruit firmness is expected to be similar. The objective of our study was to test the efficacy of the plant growth regulator AVG in improving fruit firmness in 'Stevens' and 'Howes' cranberry. The trials were conducted in East Wareham, Massachusetts, USA. Four treatments were evaluated: an untreated control, 50, 100, and 150 ppm AVG. The trial was laid out in a randomized complete block design with five replications per treatment and buffer rows between treatments and reps. The treatments were applied with 0.1% (v/v) SILWET L-77 organosilicone surfactant. Samples for assessing fruit quality and yield were collected at harvest from each treatment replication. Foliar application of AVG did not increase fruit firmness in both 'Stevens' and 'Howes' cranberry. Fruit color, weight, the incidence of fruit rot, and yield were not affected by the application of AVG in both cultivars. The application of AVG did not affect total soluble solids and titratable acidity in 'Stevens.' However, in 'Howes,' all the treatments significantly reduced total soluble solids and titratable acidity compared to the untreated control. The application of AVG with an organosilicone surfactant did not improve fruit firmness in 'Stevens' and 'Howes' cranberry. The ineffectiveness of AVG in cranberry might be by surface morphology of the cranberry cuticle which does not lend itself to penetration of sprayed chemicals compared to sweet cherry.

Keywords: *Vaccinium macrocarpon*, fruit quality, sweetened dried cranberries

P54: Endogenous ethylene production plays an important role in blueberry fruit quality and storability

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Blueberries are perishable fruits but need to sustain intense shipping conditions: it is therefore necessary to develop the best strategies to increase storage life. Storage trials, using controlled atmosphere or 1-MCP (1- Methylcyclopropene), have indicated that shelf-life extension can be achieved for blueberries by applying the proper storage conditions. However, these results are not uniformly confirmed in all studies, in which different accessions were used, indicating a probable genotype dependency.

Physiological changes associated with ripening, such as firmness decay and flavour and off flavours production, are a major determinant of berry storability. For climacteric fleshy fruit plant species, the ripening process is coordinated by a complex network of endogenous hormones, for the most ethylene and abscisic acid (ABA). Nevertheless, there is still no consensus on whether blueberry is a climacteric fruit or not.

The aim of this study was to evaluate the endogenous ethylene production of a broad *Vaccinium* germplasm selection (25 accessions) at different fruit ripening stages and after cold storage, considering also textural and volatile compound modifications. Results confirmed the high variability between genotypes with cultivars, such as “Jubilee,” “Brigitta Blue,” or “Biloxi,” characterized by a constant low ethylene production (around 0.06 nl Kg⁻¹s⁻¹), and cultivars, such as “Jersey”, “Northland” or “Bluechip”, with high ethylene production (around 3.2 nl Kg⁻¹s⁻¹) detected at full ripe stage and after storage. These differences in ethylene production are positively related with blueberry fruit storage performance based on flavour and textural alterations.

Keywords: Blueberry, ethylene, storage

P55: Effects of hot air treatment and storage temperature on 'Camarinha' (*Corema album* (L.) D. Don) postharvest quality

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Corema album (L.) D. Don, 'Camarinha' or the 'white crowberry' is a marine plant endemic of the Iberian Peninsula that can be found in dune areas along the Atlantic coast. It has the possibility to become a new niche berry crop, because its fruits have a distinct colour (white) and provide high nutritional value. The short production period, low production volume capacity and lack of uniformity in quality, as well as loss in quality during storage and transportation to the final market are major problems that are facing berry producers. In this research, fresh harvested 'Camarinha' treated with hot air (38°C - 90 min) (HAT) and without treatment (WOT) were stored at two temperature conditions (1° C and 4° C). The effect of the heat treatment and storage temperature on fruit quality was investigated during one month. The chemical parameters, pH, acidity, weight loss, solid soluble content, physical properties, colour and texture, phytochemical evaluation, total phenolic content and antioxidant capacity of the samples, were assessed. The results from the berry composition analysis obtained for fresh 'Camarinha' show an average value of 2.8 ± 0.0 pH, a total acidity of 3.6 ± 0.4 eq. citric acid *100 g⁻¹, °Brix of 7.9 ± 0.7 . It was also possible to conclude through the phytochemical analyzes performed that these berries are a very rich source of total phenolic content (54.6 ± 1.7 eq. galic acid*100 g⁻¹ FW) with a high antioxidant capacity of 3452.9 ± 153.6 TEAC*100g⁻¹ FW. Results illustrated that during storage the weight loss and colour changed significantly for all samples (HAT and WOT) at both storage conditions. The post-harvest heat treatment showed not to have a beneficial effect on fruit quality and shelf life, independent of storage temperature. The post-harvest storage at 1°C proved to be the best condition for the 'Camarinha' quality and shelf life.

Keywords: Heat treatment, storage temperatures, quality, yield

P56: Effects of 5-AzaC, an inhibitor of DNA methyltransferase, on blueberry fruit development and ripening

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DNA methylation is an important epigenetic mark involved in genome stability, inactive transcription, developmental regulation, and environmental responses. It is unclear whether the ripening of blueberry fruits is also associated with global DNA methylation. To explore the association of DNA methylation on fruit development and ripening, 5-AzaC, an inhibitor of DNA methyltransferase, was sprayed on green-stage highbush blueberry (*Vaccinium corymbosum*) 'O'Neal' fruits and the effects on berry ripening and fruit quality were investigated. The results showed that the treatment of 800 μ M 5-AzaC could promote the berry ripening at 3~4 weeks earlier than the control. In addition, fruit ripening induced by 5-AzaC was accompanied by rapid accumulation of fructose and glucose, degradation of organic acids, and rapid increase in anthocyanin biosynthesis-related gene expressions, which suggests the potential regulatory effect of global DNA demethylation on the diverse metabolic pathways related to blueberry fruit ripening and quality. Single-base resolution DNA methylome analyses of blueberry fruit are ongoing to characterize the dynamic changes of global methylation status during fruit development and ripening, and to identify methylation sites and regions associated with fruit development and ripening. In summary, our study suggests the potential role of DNA methylation on the fruit development and ripening process in blueberry. Furthermore, our studies raise the possibility of the potential application of epigenetic modification on blueberry fruit quality improvement for future production.

Keywords: DNA methylation, blueberry, fruit maturation, anthocyanin

Thank you for
participating. See you in
2024!